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THE INSTITUTE OF PHYSICS

Vol. 11 No. 9 BULLETIN SEPTEMBER, 1960

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The Teaching of Physics in Schools

This report, which is published by permission of the Organization for European Economic Co-operation, was presented to the International Conference on Physics Education in Paris in July, 1960.

The Office for Scientific and Technical Personnel of the O.E.E.C. is undertaking as part of its program a number of studies of science curricula at the secondary school level, the purpose of which is to bring the secondary school curricula into line with modern developments in the scientific disciplines. Reports on the modern approach to the teaching of mathematics and chemistry are in the final stages of preparation, and the following document was produced as part of the preparatory work now being undertaken in physics.

The report has been prepared by a working group, whose membership is as follows:— MR. NORMAN CLARKE (*United Kingdom*), Chairman; PROFESSOR A. MICHELS (*Holland*); M. A. RENAUD (*Switzerland*); PROFESSOR D. SETTE (*Italy*); PROFESSOR S. SIKJAER (*Denmark*); DR. J. TOPPING (*United Kingdom*) and PROFESSOR L. WEIL (*France*).

Our Committee was set up in order to suggest how the physics curricula in schools could be revised. It is significant and no doubt indicative of the widespread belief that such revision is necessary, that consideration has also been given to this subject by other groups in America and England. The nature of any revision is obviously determined largely by the ultimate purpose that physics teaching in schools is considered to have. Our own discussions have been based upon our strong belief that physics, the most exact and fundamental of the sciences, is a vital part of modern culture and, as such, a necessary element in the education of all children. There are some who appear to equate science with technology and who advocate the extended or more intensive teaching of science because of its probable contribution to increased material well-being. We are well aware of the economic aspects of technological development and of their importance; nevertheless, the cultural value of science—which is all too often inadequately appreciated—should be the aspect which determines the extent and the nature of the science courses in schools. Modern science has changed not only man's environment but his whole approach to many of the problems which he has to face and which his predecessors had to face. Science is not only a powerful weapon with which to attack material problems; it provides a new process of thought, and new criteria of credibility and of acceptability of evidence. Philosophy, theology, politics and economics have all been influenced in differing degrees by science, and the most powerful influences have been the result of the changing picture of natural phenomena that scientific thought has created. In the present context, it cannot be too strongly emphasized that science is one of the humanities. Physics is not a collection of " facts " which can be learned; it is a highly imaginative intellectual structure of concepts that gives a meaningful and creative picture or model of such of man's experience of the world in which he lives as it has yet been possible to integrate into a consistent whole. It is a picture that is constantly being given further detail and some parts of which are occasionally being redrawn. The reasons why physics has a place in a child's education are firstly that the story of the drawing of that picture is a remarkable tribute to the power of the human mind and, secondly, the model of nature that physics provides is a necessary component of any fruitful modern thinking about some of the most important of the perennial problems that man has to attempt to solve as a social being.

So far as this is educationally feasible, our concern is with *every* child. The needs of those children who will not specialize later in science must therefore be pre-eminent, since these children are the overwhelming majority. It is partly because this requirement has not been observed in school science courses that a drift towards " two cultures," with a false antithesis between " humanist " and " scientific," has taken place. Science should not be thought of as a subject which is to be taken only by a minority who appear to have a special attraction towards it. In the formative years of general education up to, say, the age of sixteen years, an appreciation of the intellectual power and significance of science and some understanding of the scientist's picture of the world, are as important a part of the education of all children as are history and literature. That they are not usually so regarded is at least partly the fault of scientists themselves and particularly of those responsible for the content of school science courses, which have only rarely been such as would arouse either the respect or the interest of children who had already discovered pleasure and satisfaction in the humanities. We deal with this matter in more detail in the next section.

In several European countries there is a long tradition of competent science teaching designed to prepare children for entry to the university to become scientists and engineers. Especially in the last fifteen years this tradition has been beset by problems of which the most outstanding is the increasing difficulty in recruiting able teachers. If one were concerned merely to increase the output of professional scientists and engineers, by trying to ensure that the facilities that existed before the war in the more advanced countries were now available for larger numbers of children, it would probably be to problems such as the provision of accommodation and the recruitment of teachers that one would primarily direct one's attention. In our view, however, this would miss the crucial need of the present day. The purpose of school education is to prepare children for the adult world in which they live, and for the reasons we have already given, few subjects can compare in importance with science as a necessary foundation for understanding that world. The principal years of school education should be devoted to this aim of acquiring broad understanding ; the preparation of specialists should be regarded at this stage as a secondary purpose. This is a point on which we may differ from other groups who have looked at the way in which physics should be taught. It is on this point, too, that we may receive criticism from some teachers concerned with the training of those who will become professional physicists, but we believe that any such criticism could easily be met on two grounds. Firstly, after the age of sixteen or seventeen years there is ample opportunity to make any modifications that might be needed as a consequence of changes in the basic course, and it is a responsibility of teachers of the advanced course in schools and of university teachers to make these modifications. Secondly, we believe that the kind of basic course that we have in mind should, in fact, improve the quality of specialists or at least make easier their subsequent assimilation of the more difficult abstract and mathematical aspects of physics.

Early in our discussion we faced the problem which has been referred to above, of the present shortage of well-qualified science teachers in most countries. Later in our report we have some comments to make on the problem itself but we decided at the beginning that in devising a course we had to assume that adequate numbers of good teachers would be available. It seemed profitless to assume otherwise and to plan a course that was known to be inadequate from the start. In fact, the course which we broadly indicate in this report as a suitable basic course for children of about twelve to sixteen years implies a very high level of teaching. We consider that the educational importance of physics at the present time, together with other factors to which we refer below, require that prime consideration should be given to what is taught and the way in which it is taught. If the authorities concerned accept our assessment of the importance of the problem, a way must be found of providing the consequential needs of teachers and other facilities.

DEFECTS OF PRESENT PHYSICS COURSES

The overwhelmingly important fact to be faced in considering what should be taught in the various stages of school education is that, in all countries, the majority of children complete their education not later than the age of sixteen or seventeen years. The presentation of any school subject should therefore be devised in such a way that a rounded, consistent and realistic course of a general educational nature should be offered. Children who leave school at the age of sixteen should not automatically be restricted only to a partial course devised with the needs of a specialist, who will continue for another two or more years at school, primarily in mind. To a large extent such a criticism could be levelled at most science courses at the present time. Traditional methods of teaching science have usually been based on what might be regarded as a logical system involving what is thought to be a progressive increase in the difficulty of the subject. In fact, the increasing difficulty has commonly been an increasing mathematical difficulty. The fundamental problem—that many children commonly find great difficulty in grasping some of the rather sophisticated concepts of science (such as, for example, those usually included in the earlier stages of the teaching of mechanics) has usually been ignored. From our point of view, however, the most serious criticism of traditional methods of teaching physics is that it is only in the latest stages of a course, often only in the stages that would not be taken by the children who leave school at sixteen, that there would appear to be any relationship between physics as taught and physics as even the most obtuse member of a modern community must be vaguely aware of it. From the syllabuses of many of the courses now taught to children up to the age of sixteen it would be difficult to appreciate that this is a subject of great cultural importance and of vital significance in the modern world. To most children it must appear to be extremely dull.

It is appropriate to comment here that even if one were concerned merely to produce more scientists and technicians, in order to attract an increasing number of children of high intellectual ability towards careers in science a first requirement would be that science should be presented to them at the earliest stages as a stimulating subject, intellectually satisfying and significantly related to their experience of life outside school.

In most countries of Europe where science is seriously taught it is usual for children to begin to study it at the age of twelve or thirteen. By this time nowadays most children have some familiarity with scientific terms and above all with scientific applications. They commonly have a well-developed sense of wonder and they often believe science to be exciting. Many of them (in some countries most of them) have television sets (which are remarkable pieces of applied physics and engineering) in their homes, their parents have motor cars and they read in the newspapers about satellites, nuclear power stations and radio telescopes. They then begin the study of physics and for four or five years while learning the subject from which many of the appliances of modern technology have sprung, they will hear little, if anything, of these exciting developments with which they are familiar. Instead, they will learn a number of " facts " and " laws," perhaps do a number of simple and sometimes rather pointless experiments, and in general follow a somewhat desiccated and often strongly mathematical course based upon a few elementary physical principles. These courses commonly involve no scientific knowledge that has been discovered in the last few decades. They are likely to appeal only to the small number of children who have real mathematical ability or who can appreciate the logical presentation of abstract concepts without reference to their relevance to the practical world.

There are, therefore, two main criticisms of the usual presentation of physics in schools. Firstly, it is dull and makes no conscious attempt to build upon the natural advantage which the science teacher has in the common curiosity of children about the world in which they live and their present-day familiarity with outstanding examples of applied science. Secondly, through its emphasis on what is regarded as a logical development from simple principles (which are in reality often abstract concepts of some subtlety) it is necessarily circumscribed and incomplete. It fails, and indeed could hardly be said to attempt, to give children a broad picture of what modern science is about and the way in which scientists think. To take an analogy, it is as if a foreign language were to be taught by confining the course up to the age of sixteen to an exclusive study of grammatical rules without ever introducing children to the literature of the language or allowing them to meet people who actually speak it. In our view, one of the essential requirements of any science course at this level is that it should interest and stimulate the children. Another is that the complete course should give a worth-while picture of modern science. It must therefore attempt to include comparatively new knowledge. This may involve some loss in particularity for what is gained in width, but it should be remembered that the existing syllabuses equally represent a selection of physical knowledge. Our selection is different. We believe that it has not only the advantage of far greater attractiveness to the children but the virtues of being more fundamental in its approach and of having greater cultural value.

CHILDREN FOR WHOM OUR COURSE IS INTENDED

Ideally we should like to propose a course or courses in physics that could be taken by *all* children who are not educationally retarded. It should be possible in fact to go a long way in this direction when it is borne in mind that many of the less academic children have a far greater natural interest in matters scientific than they have in the humanities. The way in which science can be taught, however, varies greatly according to the intellectual capacity of the children, especially according to their ability to appreciate abstract concepts. For this reason we have concentrated our attention on the most able group of children, those who would be found in grammar schools or their equivalent. The proportion of children in these schools varies appreciably from country to country but 15-20% is probably a reasonable general estimate. In most of these schools physics would be taught already to many of the children, especially to boys, and there would usually be some specialist teachers of physics and some facilities for experimental work. These facilities vary greatly between countries and within countries. Our suggestions represent the optimum course. Because of the different facilities of the various countries, the adaptation of our recommendations would be a matter for national authorities. It would also be a matter for national consideration as to how a course of this general character should be modified for children of lower intellectual ability.

THE APPROACH TO THE TEACHING OF PHYSICS

Great importance must obviously be attached to the subject matter of a course and the way in which it is developed as a logical whole ; of even greater importance is the way in which the teacher handles the subject matter. We wish therefore to stress what is perhaps a truism, that the quality of mind of the teacher and his approach to the subject are crucial to good science teaching.

Although physics should be taught as a separate subject, the teacher should take every opportunity of stressing the unity of the physical sciences and, indeed, the applicability of some of the methods of the physical sciences to other sciences. The way in which this can be done must be left to the initiative and judgement of the individual teacher but it is important that close co-operation should take place between the teachers of physics, chemistry and mathematics.

Whenever the teaching of physics is discussed and particularly when it is suggested that a new approach may be needed, it is common to find ideas put forward that are basically those of the so-called " heuristic " method which had considerable vogue some years ago, and which is based on the belief that children learn science by " discovering " things for themselves. An aspect of this attitude that one finds in some quarters is the reliance on experiments using large, simple and commonly available apparatus as a means of leading children to the acceptance of scientific laws and principles, especially in mechanics. While there is obviously something of value in these points of view, much time can be wasted and it is doubtful whether, in fact, children get any real glimmer of scientific method or scientific principles in these ways. There are some things that some children can learn for themselves, but in general children need to be guided to what they find out. The uses which may be found for methods of this kind must ultimately be a matter for the individual teacher to decide but we are sceptical of the inherent value of this approach.

In discussing the aims of science teaching in schools, it has become almost platitudinous to lay great emphasis on the importance of careful and accurate observation. No scientist will belittle the importance of observation as a necessary part of that whole process of activity that we describe as science, but it is dangerously easy to overemphasize the place of observation, especially when dealing with the children less able to grasp abstraction. In fact, the essential element in science lies in the concepts, some of which are difficult and some of which are highly abstract. All of these concepts are products of the human mind and it is their development which has alone made possible the transformation of observational data into a consistent and logical picture of the universe. No course in science is worth offering unless it is likely to ensure that children will not only gain some familiarity with the more important of the concepts but will begin to understand the crucial place of " theory " in science and its interrelation with experiment. It is common to stress that theory follows observation and hypothesis and is ultimately checked by further reference to experiment. This is an inadequate approach to the process of scientific investigation, for not only does it make no reference to " physical insight " (which may be a difficult idea to convey) but it ignores the place which concepts, or a physical picture of phenomena, have had in the work of the greatest experimentalists. The link between experiment and theory is intimate and the two are hardly separable ; the greatness of the most outstanding experimentalists such as, for example, Rutherford or Faraday, lay not only in their ability to see the significance of experiments but in the clarity of their tentative " theoretical " picture of the physical phenomena involved, which enabled them to decide upon the right experiments to perform. There is no respect in which the teacher's attitude of mind is more vital than in his clear appreciation of this relationship of theory and experiment.

In the course that we outline there are some sections that might best be dealt with by introducing first a wealth of experimental data, through demonstrations performed by the children themselves, and subsequently leading them to see the theoretical significance or explanation of these data. There are other topics which could not effectively be dealt with in this way and where the teacher should unhesitatingly discuss theory and rely only upon a limited amount of experimental evidence to suggest the plausibility of the theoretical picture. A weakness of some conventional courses is that teachers are disinclined to give theoretical knowledge " on trust " in this way, but in practice the professional scientist takes the greater part of his knowledge on trust from the experimental work of others and there is no reason why children should not do so. Moreover, unless this is done a course may have to be restricted to the less interesting branches of the subject. The professional scientist has had to learn, of course, how to decide what he may take " on trust." It is a necessary part of a good physics course that the student should acquire some criteria of credibility and trustworthiness of data.

Later in this report we discuss other aspects of the way in which the subject should be dealt with. It is perhaps necessary to mention now only one other point. This is that we have ignored in our discussion the conventional divisions of physics into heat, optics, mechanics, etc. It may be necessary in published syllabuses to retain some of these divisions but the divisions should not be apparent in the teaching. Physics should be presented as a unified whole with stress upon the universality of physical laws. Above all, the course from the very start should be based as far as possible on modern ideas.

The course that we propose is intended to extend over four years with an average of three or four periods a week. We expect that physical science would be taught as a separate subject from about the age of twelve or fourteen ; some schools might wish to give in addition a preliminary course of a rather more general scientific nature, extending over either six months or a year.

Our suggested course is discussed below. It is perhaps desirable to comment first on our suggested way of *introducing* physics. We appreciate that there are substantial reasons to support an introduction through mechanics, which is, in fact, the way in which the subject is usually begun in schools. Mechanics is the foundation of physics and one cannot get far in the subject without a firm grasp of some of its concepts. Nevertheless, even if one strips away much of the conventional overlay of rather futile experiments with pulleys and the all-too-common over-emphasis on numerical examples, mechanics can be a deadening subject, especially as an introduction to science for children who have some interest in the more modern aspects of physics. We have recommended that the introduction to physics should be through a consideration of atoms, molecules and electrons. We do this for two main reasons. Firstly, most children these days are aware of the terms and have at least a vague idea that matter consists of these entities. A teacher is therefore able to begin the course by building upon the children's interest and by dealing with a branch of the subject which also has the virtue of being able to provide a good deal of stimulation. Secondly, and more importantly, the teacher should start from the very beginning to present physics in as modern terms as possible. Children should obtain an early grasp of the idea that the physical world can be interpreted in terms of moving particles and of wave motion. Naturally, as the course develops the teacher will extend and develop his treatment of the properties of atoms, molecules and electrons in the light of other knowledge which the children have then acquired, for we expect that he will adopt a " concentric " system of teaching. In the introductory part of the course the treatment will have to be general and descriptive with a reliance upon good demonstration experiments. As early as possible the teacher should also endeavour to introduce simple ideas of chance and elementary statistical concepts.

We appreciate that to begin by discussing atoms and molecules will involve some lack of continuity when mechanics is introduced, but we consider that the reasons we have given above are more than sufficient to justify this possible disadvantage.

We do not propose to give a detailed list of topics that ought to be included in the course. Below we give a broad outline of what ought, in our view, to be the basis of the course and some rather more detailed items are mentioned simply to give some indication of the way in which we think the subject matter should be dealt with. It should certainly not be assumed that these items represent the range of the subject matter. It will already be clear that we are concerned essentially with the basic approach of the teacher and with his appreciation of what are the fundamentals of physics. We wish to recommend a new order and a new method of presentation of physics : to some extent the actual subject matter will depend upon the individual teacher. Moreover, a teacher who devised a course along the lines we suggest might wish to modify it in significant detail in the light of experience. On detailed content, therefore, it would be improper to dogmatize. What we are emphatic about is the broad pattern of the course.

Bearing in mind that the teaching should be " concentric," as we remarked earlier, the course should be along the following lines :

(*a*) The particle nature of matter. General ideas of the differences between atoms, molecules and electrons.

(*b*) Beginning of an understanding of the basic concepts and laws of mechanics, with an emphasis on the physical significance of the concepts.

Note : we wish to emphasize that we are *not* suggesting that a long and intensive study of mechanics along conventional lines should be given. The teacher must spread the development of the mechanics over the course. Nor are we suggesting a single method of introduction to mechanics. The most basic of the concepts is energy and some teachers would wish to begin with a consideration of energy ; on the other hand, other teachers might feel that " force " is a concept more likely to be intuitively grasped by children, and to use this as the starting point without implying that it is the most important concept. Whatever the teachers' experience might suggest as the most appropriate way to begin, the children should eventually have a firm grasp of the physical significance of energy, work, force, velocity, acceleration, mass, momentum; the conservation of energy and momentum. They should know something of the measurement of time.

(*c*) The simple properties of gases and vapours ; ideas of temperature and pressure as phenomena of particles in motion : states of matter and change of state in terms of aggregations of atoms and molecules ; chemical bonds.

(*d*) Measurement of temperature and the transfer of heat ; the laws of thermodynamics ; the energy supply available in nature.

(*e*) The structure of atoms ; electrons as carriers of electricity ; electrostatics ; thermionics ; electromagnetism ; magnetism.

(*f*) Mechanical, acoustic and electromagnetic vibrations.

(*g*) Light as electromagnetic radiation ; geometrical optics ; diffraction ; interference ; emission and absorption of light ; simple ideas of quantum theory ; emission of X-rays.

(*h*) Radioactivity ; structure of the nucleus ; nuclear reactions ; equivalence of mass and energy ; elementary introduction to relativity.

The following notes should be borne in mind :

(1) Throughout the whole course mechanics should be taught as a *science*, with a constant appeal to nature, and should not be allowed to degenerate into a branch of applied mathematics. There should be no excessive emphasis on numerical examples. Teachers of mathematics who commonly take examples from mechanics to illustrate their own teaching, should avoid the physically unrealistic and stereotyped mechanical examples which have been so commonly used. Similarly, in the treatment of vibrations and wave motion, to which we attach importance, the phenomena should be treated as primary.

(2) The emphasis on particles and motion should enable the teacher to move easily from one conventional branch of physics to another and to avoid the impression in the mind of a child that physics is merely a collection of self-contained subjects.

(3) Throughout the course the teacher should take opportunities of referring to modern developments. Particularly will this be desirable in the section on nuclear physics where, as far as is possible, an outline of important modern developments and concepts should be given. At the same time, the teacher should not consider that it is his function to present a course on modern physical technology. Indeed, he should endeavour to make the children realize the difference between science and technology.

(4) We have mentioned earlier that close contact should be maintained between teachers of physics and chemistry. It is perhaps worth remarking here that the approach that we have adopted to the presentation of physics should be particularly helpful to the teachers of chemistry.

(5) We have made no specific reference either to the philosophy of science or to the history of science but we believe these two subjects to be extremely important. However, at this stage they must be taught largely incidentally. The teacher ought to take every opportunity that he can to familiarize the child with the way in which ideas in physics have developed in the course of time. He ought to ensure that children know about some of the great classic experiments and developments, without making a fetish of these and without requiring the children to know more than the significant features of them. At all stages of the course he must stress that in physics, as in all science, theories are never fixed and absolute but may be modified and discarded as new knowledge emerges or as men begin to think in new ways about old knowledge.

PRACTICAL WORK

We have given considerable thought to the question of practical work. In different countries the importance attached to practical work varies enormously. In some, it appears to be the usual practice to rely entirely on a limited number of demonstrations by the teacher ; indeed, in some countries only a small number of schools in which physics is taught would have laboratories in which the children themselves could undertake experiments. On the other hand, there are other countries, notably Britain, in which very great emphasis is put on the carrying out of experiments by the children. In many English schools about half the time devoted to physics would be spent in this way. In our view the desirable practice lies somewhere between these extremes. If the children begin to study physics at the age of twelve or thirteen, then in the early stages of the course emphasis should be placed on demonstrations carried out by the teacher rather than on practical work done by the children themselves. Practical work should be introduced progressively, initially with an emphasis upon measurement, the development of manual dexterity and of accuracy in observation. Initially the practical work should be done in the ordinary lesson and should not be organized as separate periods. With the introduction of quantitative measurement should come also the idea of assessing the error involved. Manual ability is useful but need not be acquired in a laboratory. All children in schools where science is taught should have the opportunity of working in wood, metal and glass, but a good deal could also be done in this direction in the junior schools which children attend before entering grammar schools. The whole question of practical work and demonstrations is of sufficient importance to justify further more detailed investigation. The quality of teaching of physics, especially in the earlier years of the course, could be greatly increased if teachers could be given more guidance on the sort of demonstrations that might be given and, of course, if they all had the necessary equipment, and the appropriate technical help to enable them to make the best use of it. Equally, an investigation into the kind of practical work most appropriately done by children would be useful. In England and other countries, much of this work is somewhat futile, consisting of the measurement of standard quantities by methods that might be of some historical interest but would not be used by any practising physicist. It would be useful to consider how far entirely new types of practical work, such as project work, ought to be developed.

THE TEACHING OF MATHEMATICS TO PHYSICS STUDENTS

It is sometimes maintained that some children who like physics and have reasonable ability in the subject find it unduly difficult because they have no mathematical aptitude or because mathematics is badly taught. This is a subject on which it is extremely difficult to generalize although it is clearly of considerable importance in relation to any proposals for the teaching of physics. We believe that there may be validity in the argument concerning mathematical aptitude, but from our discussion it would seem that there are big differences between different countries in the extent to which the teaching of mathematics can be judged by physics teachers to meet their needs. In some countries it would seem that the teaching of mathematical techniques in schools is on the whole fairly satisfactory but that co-operation between teachers of physics and teachers of mathematics is not always sufficiently good. If the teaching of techniques is adequate the physics teacher then has a special responsibility to help his students to learn how to apply their mathematical knowledge to physics problems. He should avoid the use of mere mathematical exercises. Teachers of the two subjects can help each other if they try to co-operate in the matter of gradually introducing abstract ideas.

In thinking about our basic physics course we have assumed that children would normally begin to learn algebra at about the age of thirteen or fourteen and either then or in the following year would be given simple ideas of function and graphical representation. By about the age of fifteen they ought to be able to solve quadratic equations and to use logarithms. After a further year it is hoped that they would understand the idea of a limit and would be familiar with first and second derivatives of a function. A common weakness of mathematics teaching, from the physicist's point of view, would seem to be the lack of proper attention to numerical methods, methods of approximation and elementary statistics. These should all find a place in the mathematics course taken simultaneously with our basic physics course.

AN ADVANCED COURSE FOR THE NON-SPECIALIST

We believe that all children should take a course in physics as part of their general education. We also believe that there is a strong argument that all children who stay at school beyond the age of sixteen should continue their study of physics as is done, for instance, in France. At this level those who are intending to go to the university to specialize in science, engineering, or medicine would obviously need a specialist course, to which we refer below, but it is equally desirable that those children who will specialize in the humanities should also devote some time to a course in physics. We do not think that it would be appropriate to suggest a detailed syllabus for this course but it should outline in rather general terms some of the modern developments in physics and should also deal, at a deeper level, with philosophical implications of physics. It should show the children the way in which the emergence of modern science has influenced men's thinking about philosophical problems and it should include examples of difficulties of a philosophical nature which the scientist himself has had to face. At this level, too, it should be possible to develop still further the appreciation of the unity of science. The content of the course should not, of course, be primarily philosophical and one of the aims should be to develop the children's knowledge of some of the branches of the subject which could be chosen largely according to the interest and ability of the teacher concerned. It would be of interest to children of this kind to read for themselves some of the classic papers and books that are landmarks in the history of science.

Once again we think it is useful to repeat the warning that the teacher of this course should make children appreciate the distinction between science and technology. In the discussion of modern developments in physics and applied physics he will certainly wish to discuss the impact of physics on our social system and on our economic development, and it is necessary that children should be aware of the importance of technological development. Nevertheless, the teacher should seek constantly to make pre-eminent the development of scientific knowledge as distinct from its application.

AN ADVANCED COURSE FOR THE FUTURE SPECIALIST

A boy who has decided that he wishes to continue to study physics seriously at school with a view to entering a university or similar institution would, if he had followed a basic course such as the one we have described, already have a broad picture of physics and would have been introduced to an elementary outline of some of the most interesting although difficult aspects of the subject, including those in which modern advances are expected to be made. He should have realized already that physics is not a series of dull facts, formulae and standardized experiments, but that it is an impressive structure giving an interpretation of the material world that is challenging and demanding. He may begin to appreciate that significant advances in physics rest upon insight and imagination, elegance in experiment and creative intellectual power in the translation of experimental data into theoretical concepts. As much as anything we hope that a result of the adoption of the kind of basic course that we recommend would be that boys and girls who were scientifically inclined and hoped to become specialists would by the age of about sixteen have acquired real enthusiasm for physics. This is at least as important an objective at which to aim in preparing the future specialist as the mere acquisition of factual knowledge.

The purpose of an advanced specialist course is twofold. Firstly, the student must acquire more extensive and more detailed knowledge of the subject. Secondly, this must be done in such a way that he is gradually led into those habits and attitudes of mind which will enable him to get the greatest value from his university study and to be successful subsequently in scientific work. The actual subject matter of the advanced course should be flexible and offer considerable choice to the teacher. Essential parts of the subject that need to be developed in scope and in intensity are, however, mechanics, thermodynamics, electricity and the physics of the solid state. Thermodynamics should be taught in a way which will allow the student to begin to appreciate that this is a basic subject that links physics together ; for the same basic reason, further emphasis should be put upon vibrations and wave motion. In addition to the development of physical knowledge in this way, the advanced student should also take the course that we have suggested for the non-specialist although, for him, the emphasis on different parts of that course may be different from the emphasis given for the non-specialist. Such parts of this course as are common should be taken by the two groups together.

We are, however, concerned that our future specialist should begin to see and to think about his subject as a whole. This is one of the really necessary attitudes of mind for the successful study of science at the university. To this end he should be taught to consult some of the great literature on the subject, to be able to write simply and clearly about physics and to learn to study rather than to expect to be taught. These attitudes of mind are more important for him on entry to the university than the possession of a specified body of knowledge and technique.

Once again we draw attention to the need for a reconsideration of the place of experimental work. Even more than in the basic course, the course for the specialist should introduce a new and fresh approach to practical work and should avoid the performance of standardized experiments. At this stage particularly, project work would be of considerable value. One of the principal aims of the practical work should be the development of familiarity with instruments, with an understanding of the scope of their usefulness.

EXAMINATIONS

A major problem in any consideration of educational development is the impact of the examination system. This is particularly important in those countries where school examinations are held on a national basis and where there is, therefore, some temptation to a teacher to adjust his course and his method of teaching so as to ensure that his own students have the best possible chance of passing the examination. Within reason this is not objectionable, but it can obviously be greatly abused. Even if the teacher's own attitude is not unduly biased in this way, however, the impact of the examination system can have unfortunate repercussions on the content of school physics courses. This arises from the fact that certain branches of the subject may be easier to examine than others, and, even more, that certain kinds of examination questions are easier to use than others in examinations where large numbers of students are involved. For example, in England the largest of the nine examining bodies for school examinations, the Northern Universities Joint Matriculation Board, examines more than five thousand children each year in Advanced physics, which corresponds to the end of the specialist school course and is taken at the age of about eighteen. The total number of boys and girls examined in physics in 1958 by the nine examining boards was 51,000 at Ordinary level (aged about 16) and 26,000 at Advanced level (aged about 18) ; the numbers are increasing steadily and, in fact, more children take physics at Advanced level than any other subject. This means that examinations of this kind must be written examinations and it is usual for children of this age in England to take two papers, each of three hours, and a practical examination. For examinations conducted on this scale it seems to us to be extremely important, in relation to the kind of attitude that we are advocating for the teaching of physics, that examiners should not adopt the easy method of asking questions that merely require the memorizing of information. More important still, no undue emphasis should be put on numerical exercises involving standard formulae which children can be taught to answer without really understanding the underlying physics. In countries where the tradition of examining is to rely on oral methods the problems are somewhat different, particularly in that the difficulty of excessive use of numerical examples does not arise. We should, in fact, like to see thought given to ways of examining a subject like physics ; a combination of written and oral examinations might be the right one. We see no virtue at this stage in holding practical examinations.

For examinations in subjects such as the physics course for non-specialist advanced students, schools should have wide freedom to devise their own syllabuses on which the examinations are based.

THE SUPPLY OF PHYSICS TEACHERS

The quality of any course is limited by the quality of the teachers available and we are well aware that most European countries face a serious problem in recruiting science teachers at the present time, although the severity varies from country to country. We are equally conscious that we are in this report demanding a very high level of competence from those who teach physics. If the physics course is handled as we think it should be, it will place demands on teachers that are heavier than the demands made by most of the present courses. It is therefore appropriate that we make some comments on the problem of teacher supply as we see it, although we recognize that any solution involves matters of policy entirely outside our purview. Perhaps the first point to stress is the importance of keeping a sense of perspective. Most European countries have, in fact, very many good teachers of physics although most of them are probably middle-aged. The solution of the problem does not require a major reorientation of the fields of employment of physicists, but it does require that the recruitment of good physicists to the teaching profession should be increased by an amount that ought to be well within the capabilities of most European countries.

Some of the solutions offered merely amount to the suggestion that the salaries of teachers need to be increased. In some countries inadequate salaries may be the most important factor affecting the supply of good teachers, but this is by no means the only problem that needs to be considered. The outstandingly good physicist could undoubtedly earn more in some other branch of the profession and this will always be so because teaching is one of the few occupations where there are rigid salary scales that allow comparatively little differentiation between people of varying merit. The teacher whose ability as a physicist is only of an average level, on the other hand, can in some countries earn about as much as he would probably receive in other fields. Moreover, we understand that in some countries where teachers' salaries have been increased there has been no obvious increase in the number of entrants to the teaching profession. The difficulty seems to us to be of a different kind and to be related much more to conditions under which the teacher works and to the prestige which his occupation enjoys.

There are probably two broad groups of people who enter the teaching profession as teachers of science. Firstly, there are those who have a strong desire to be " educators " and who derive great satisfaction from helping children to learn and to develop as human beings. To these people the subject which they teach is of lesser importance than the fact of teaching and it becomes largely a vehicle through which they can exercise a beneficent influence on young people. The second group consists of people whose prime interest is in their specialist subject but who enjoy teaching it, especially at the level of the senior forms of a school where they can teach children who are beginning to appreciate and to enjoy the more interesting and advanced parts of the subject. This distinction is highly relevant to the problem of recruiting physics teachers. It sometimes seems to be assumed by Ministries of Education and similar bodies that all teachers are of the first category, and almost nothing is done to provide the necessary conditions under which the men in the second category, almost certainly the large majority of those who teach physics, can find satisfaction in their work. When an able young man has taken his degree in physics he has before him a wide choice of posts that will allow him to work actively in the subject for which presumably he has some enthusiasm. To such a young man these days it may well seem that to become a school teacher of physics is to cut himself off from physics as a subject. This, in fact, is all too often what does happen. It would therefore seem to us to be a crucial factor in any attempted solution of the problem of teacher shortage that those who teach a rapidly expanding and advancing subject like physics should be given ample opportunity to maintain contact with their subject and with colleagues in the universities and industry. We are advocating a course based on modern ideas and it could be taught only by teachers who had adequate time to keep themselves abreast of developments. It is necessary not only to secure good teachers but also to maintain their abilities at a high level. A suggestion that might be considered is the establishment of an international institute to which teachers could periodically go for refresher and advanced courses of three months or so. A small number of teachers who have the necessary ability and who feel drawn towards investigational work could be given the facilities to do research on a small scale, but this would be possible only if they had easy contact with the universities. It would be possible also only if their teaching load was kept at a reasonable level. In this and in other ways it should be made clear that teaching offers opportunities of satisfaction not only for those who are " educationalists " but also for those who wish to continue to regard themselves as physicists. The general institution of sabbatical years might do something to help in this direction.

A major problem mainly outside our purview is the question of social prestige. There is a good deal of variation from one country to another but to differing extents it would seem that the prestige attaching to teaching in the minds of the general public, and of the young graduate in particular, is substantially less than that attaching to other occupations which the young physicist may enter. This may partly be due to an insufficient distinction, in status and salary, between, on the one hand, the teacher of general subjects in the junior school or the less well-qualified grammar school teacher, and, on the other hand, the highly qualified teacher of a specialist subject such as physics. We do not feel able to suggest ways in which this matter can be resolved but we think that it is one of some importance. Perhaps something would be done to improve the position if there were greater opportunities of movement and promotion between the various fields in which physicists work. As an example, it ought to be possible for some outstanding teachers of physics to secure university posts, and possibly a few might have joint posts in university and school. It ought to be made easy also for the physicist who has spent some years in industry or elsewhere to move to a teaching appointment if he has the right qualities. In some countries, of which Britain is one example, the salary structure makes this virtually impossible because no credit would be given in assessing the salary to the years spent in industry.

TEXTBOOKS AND TEACHING AIDS

We hope that in this report we have indicated sufficiently clearly the broad outline of the sort of course that we would like to see introduced and have indicated also the attitude of mind that should inspire the teacher. It would be impossible in such a report to go into more detail concerning the subject matter of the course which will, we hope, be obvious enough to the first-class teacher. As a help and inspiration to teachers, however, especially those who have only limited experience, a book based on these ideas would be a virtual necessity. In the principal European languages there is already a good choice of textbooks, especially in English and French. Nevertheless, although we could find in some of these books sections that would be broadly in line with our views, there is no book, so far as we know, that could be recommended to any teacher who wished to give the course we have suggested. It therefore seems to be highly desirable that serious consideration should be given to the preparation and publication of a book to support our suggested course. Probably a co-operative effort by several authors, under the general editorship of someone wholly in sympathy with our views, would be the best method, but this would be a matter for discussion. We have little doubt that a publishing house could be found that would be very willing to accept the financial responsibility of publication. If this were done special consideration should be given to the needs of the smaller European countries. For countries whose mother tongue is spoken by few people the provision of a reasonable range of textbooks is a major problem and it might be necessary to subsidize the further publication of editions translated into such languages.

A useful contribution to physics teaching, especially where there is any lack of demonstration equipment, would be made by a series of up-to-date films. There should be a large market for such films if they could be simultaneously produced in several languages.

Regular exhibitions (say every two or three years) of experimental equipment, organized internationally, would also be valuable.

CONCLUSION

We hope that we have made clear in our report that we believe that it is necessary to change completely the content of school physics courses, the attitude of mind of the teacher towards his aim and the purpose which the teaching of physics is considered to fulfil. Nothing less than a radical change will suffice if we are to succeed in giving to children, as part of a liberal education, a worth-while introduction to an understanding of the place of science in their lives and the method by which science is carried on and advanced. There are few who do not now realize that the advancement of science and its extended application are essential for the health and growth of modern economies. Such a recognition is not, however, sufficient. We need to educate children to appreciate that science is, in fact, one of the humanities and a major part of modern culture. To a non-specialist as much as to the specialist, science is worthy of study for its own sake irrespective of the value of its applications.

NORMAN CLARKE,
Chairman.

The International Conference on Physics Education: Paris, 1960

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On Thursday, July 28, about 100 delegates from 29 different countries assembled at the Unesco House in Paris for a conference on physics education. The conference was initially proposed by the International Union of Pure and Applied Physics. It was organized by an international committee under the chairmanship of Professor S. C. Brown, Massachusetts Institute of Technology, U.S.A., and with Mr. N. Clarke of The Institute of Physics as secretary. Additional sponsors of the conference were Unesco and O.E.E.C. Financial support was also provided by the American National Science Foundation. The United Kingdom delegation comprised H. F. Boulind, N. Clarke, G. K. T. Conn, H. W. French, M. R. Gavin, J. M. A. Lenihan, G. R. Noakes and J. Topping.

GENERAL

The conference lasted for eight days during which there were twelve discussion sessions devoted to different aspects of physics teaching from elementary school work to postgraduate courses in universities. Some of the sessions were concerned with the broad fundamentals—the principles, philosophy, and objectives of physics teaching ; others dealt with more specific problems like examinations, practical work, student selection and teacher training. The subjects of discussion and the opening speakers are listed in the conference program at the end of this report. Forty-four papers* and pamphlets were circulated in advance and these formed some basis for the discussions.

Selected films were shown every day of the conference and there were exhibitions of laboratory equipment and books. In spite of all these very full activities there was still some time left for social events, which included visits to Chartres, Versailles and the Palais de la Decouverte. On the opening evening the delegates were entertained at a cocktail party at Unesco House and the conference concluded with a banquet at the Chalet des Iles in the Bois de Boulogne ; the hosts were the Société Française de Physique.

A book based on the conference proceedings and the circulated material will be published in due course, probably before the end of 1960 ; it has already been written by Professor Brown and Mr. Clarke and the MS. is now with a publisher. This preliminary report emphasizes some of the high lights.

PHYSICS IN GENERAL EDUCATION

Mr. N. Clarke (U.K.) opened the discussion, using as a basis the report (40) which had been prepared by a working group for O.E.E.C.† This challenging report was founded on the belief that " physics, the most exact and fundamental of the sciences, is a vital part of modern culture and, as such, a necessary element in the education of all children ". Mr. Clarke developed this theme most convincingly, and at the same time emphasized how far present courses in schools fail to bring out the cultural

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*Several of the papers will be published in full in the *Bulletin* in the course of the next few months.

† See page 217 of this *Bulletin*

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importance and significance of physics. He proceeded to outline a possible new approach to the teaching of physics. His scheme started off with the particle nature of matter before attempting any mechanics. This proved in the subsequent discussion to be a controversial point. However, any disagreements in detail were insignificant in comparison with the general approval of the spirit and philosophy behind his proposals.

EXPERIMENTS IN PHYSICS TEACHING

Perhaps the most stimulating session of the conference was that in which Professor J. Zacharias (U.S.A.) described the work of the American " Physical Science Study Committee " at M.I.T. which was set up in 1956 to " create a modern course in physics for secondary schools and to prepare materials for such a course " (41). About five million dollars have been spent on this work and now there is a one year course, with textbooks, laboratory work and films, which has been tried out in numerous schools with most promising results. The one year of intensive study comes in the final year of the secondary school, after the students have had a year or two of general science. The course starts off with light and optics (to interest the girls) and presents an integrated treatment of particles and waves with the final objective of providing an understanding of the atom of Rutherford, Bohr and Heisenberg. All this is done in one year ! It is hoped to extend the experiments to other years and even to the elementary schools. The success of the scheme is acclaimed by all those taking part. The delegates at the conference were most impressed, not only by the enthusiasm of Professor Zacharias and his colleagues but also by some of the films, experimental equipment and books which were on show. Complete textbooks for the course will be available soon.

Under the heading of experiments in education the sandwich courses for the Diploma in Technology should be mentioned. Discussion of these courses arose in several sessions and considerable interest was shown by delegates from other countries. It is interesting to note that a very similar sandwich course has been introduced in the U.S.A. for the purpose of increasing the supply of teachers.

The need for further experiments in physics education was stressed on numerous occasions. Some interesting attempts to evaluate the efficacy of different methods of teaching have been made in Japan (17).

POSTGRADUATE TRAINING OF PHYSICISTS

Dr. C. G. Suits (U.S.A.) speaking as an industrialist discussed some of the problems of postgraduate training in universities. He was somewhat concerned that the university physics departments were mainly interested in nuclear and high energy physics whereas industrial developments were more concerned with solid state physics. He felt that the latter provided a broader basis for fundamental training in research. On the whole his firm was reasonably satisfied with the Ph.D. recruits from universities but he agreed with many of the criticisms expressed in the British report published by the Institute (43).

FILMS AND TELEVISION

Professor Harvey White (U.S.A.) described some of the experiments he had conducted in the use of television for teaching physics (36). At the same session Professor W. Kelly (U.S.A.) stated the case for and against the use of films as a teaching aid. Both speakers emphasized the paramount necessity of setting and maintaining a high standard of presentation. Provided this is achieved they were convinced that films and television could make a useful contribution to physics teaching. Some of the merits of these methods of presentation are :—

(i) they allow students to see experiments which are too difficult or dangerous for the classroom,

(ii) they allow students to hear and see famous physicists working in their own laboratories,

(iii) they allow all students to have the " best view ".

(iv) there are special film techniques such as speeding-up or slowing-down, split screens showing two or more things simultaneously, etc.

In the subsequent discussion many speakers expressed concern over the loss of personal contact between teacher and pupil. Even the most ardent advocates of films and television agreed that this is a serious matter and that these aids should be at best a supplement to the good teacher. However, they might be of great value in cases of teacher shortage and even for the presentation of elementary physics with non-specialist teachers.

By the end of the conference most delegates were convinced of the great value of the right kind of film as a teaching aid. Perhaps the most impressive evidence lay in the actual films which were shown throughout the conference.

CONCLUSIONS

Any report of this conference would be incomplete without some reference to the many interesting contributions of the French delegates, both from the platform and the floor. One was frequently conscious of their leaning towards the theoretical side of physics. Professor Aigrain, who was perhaps more experimentally minded than most of his compatriots, created a minor disturbance by referring to physics as a branch of applied mathematics !

In a conference of this type it is inevitable that a large part of the time is taken up with detailed explanation of what is done in different countries. The conditions and facilities vary greatly from country to country, and it is almost impossible for those from countries with long traditions of scientific and technological education to appreciate the enormous difficulties of their colleagues in the less-developed countries. At the same time the use of a foreign language restricts some of the delegates and makes precise communication difficult. In spite of these difficulties in communication the conference was very successful. It is felt that all the delegates gained valuable information and stimulation. Perhaps the most useful part of conferences is the making of new and renewing of old friendships, which permit of informal discussion and exchange of views which inevitably stimulate and encourage—not only by providing new ideas but in discovering that one's own problems and difficulties are by no means unique.

At the end of the Conference five resolutions were passed and the following document was issued:—

" The Conference has accepted, without dissent, the following resolutions. Some of the comments and recommendations concerning education in physics may apply to education in other subjects, and we are particularly aware that similar consideration might profitably be given to the teaching of chemistry and mathematics, subjects which need to be taught effectively if the efforts of even the best physics teachers are not to be seriously impaired. However, since this Conference has been composed exclusively of physicists, we have limited our comments and recommendations to the subject on which we may claim to speak with authority. We resolve as follows:

I. In our view physics is an essential part of the Intellectual life of man at the present day and the study of physics provides a unique interplay of logical and experimental disciplines. Studying physics and the physicist's methods of acquiring and evaluating knowledge should therefore be regarded as a necessary part of the education of all children.

II. In many countries education in physics, both for non-specialists and for future specialists, is unsatisfactory. In all countries improvement is essential at some levels of teaching. Experiments have been initiated in some countries to try to find ways to make improvements; we welcome and encourage such experiments. They are particularly necessary and important at the level of secondary schools or their equivalent. Experiments and solutions will

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probably take different forms in different countries. We should like to see one or more international institutes established, among their functions being the devising and carrying out of experiments of this kind.

We recommend to the International Union of Pure and Applied Physics that it should take appropriate action, possibly in collaboration with other international organizations, to establish an international committee of professional physicists to accept responsibility for:

(*a*) The collection, evaluation and co-ordination of information and the stimulation of experiments at all levels of physics education.

(*b*) The suggesting of ways in which the facilities for the study of physics at all levels might be improved in various countries.

(*c*) The collection and evaluation of information on methods used for the assessment of standards of performance of students of physics and for the evaluation of the qualifications and effectiveness of teachers of physics.

(*d*) The giving of help to teachers in incorporating modern knowledge in their courses.

(*e*) The promotion of the exchange of information and ideas among all countries by methods that would include the holding of international conference.

III. We ask our Chairman, Professor Sanborn C. Brown, to accept on our behalf the invitation of the Secretary-General of the International Union of Pure and Applied Physics to attend the Ottawa meeting of the General Assembly of the Union, to present the resolutions and recommendations of this Conference, of which the Union was one of the sponsors, and in particular to ask the Union to accept the responsibility proposed in Resolution II.

IV. We stress that efficient instruction in physics requires specialized teachers who can keep abreast of developments in a rapidly growing subject. We are alarmed at the present shortage of such teachers, particularly in view of the growing demand for physics education. The shortage is likely to become more acute in the years ahead.

In our opinion steps should be taken to improve both the efficiency and the attractiveness of physics teaching as a profession. In so far as the realization of these aims requires action by Governments and universities, we recommend that these bodies should consider the following general conclusions:

(*a*) In schools of secondary and higher levels, physics should be taught by physicists, that is by men and women who have received a professional training in physics. Teachers must be encouraged to keep their professional experience up to date. The experimental nature of physics places an added burden on the teacher and this must be recognized and adequately compensated by a reduction of his teaching hours and in other suitable ways.

(*b*) To make teaching careers more attractive, improvements of salary and status are necessary in some cases, but most important are better conditions of work. For example, technical assistance and liberal provision of apparatus are vital and facilities should be provided for all students at all levels to carry out experiments.

Secondary school teachers should have conditions in which they can feel that they form an integral part of the development of physical knowledge.

(*c*) Universities and comparable institutions should accept their responsibility to establish close relations with secondary school teachers, to assist in solving the problems of instruction in school and to provide refresher courses. These courses would require extended periods of study leave for teachers.

V. As members of this Conference, we have derived great benefit and stimulus both from its deliberations and from the opportunities for discussion. We recommend that further such international conferences be held from time to time to examine and discuss the problems of physics education. In future conferences it may be considered desirable to restrict somewhat the range of topics discussed."

UNESCO HOUSE, PARIS *August 4, 1960*

CONFERENCE PROGRAMME

July 28

Opening Address, Professor Rocard (*France*).

" Physics as part of general education," Mr. N. Clarke (*U.K.*). Chairman: Professor Samborn C. Brown (*U.S.A.*).

July 29

" Selection of students," Professor G. K. T. Conn (*U.K.*); "Examinations ", Dr. H. F. Boulind (*U.K.*). Chairman : Professor D. Sette (*Italy*).

July 30

" The work of the American Physical Science Study Committee ", Professor J. Zacharias (*U.S.A.*). Chairman : Professor A. Michels (*Holland*).

August 1

" Practical work in the teaching of physics ", Professor M. R. Gavin (*U.K.*). Chairman : Professor W. Kroebel (*Germany*).

August 2

" Teaching of physics to engineers, chemists, etc.", Professor P. Aigrain (*France*). Chairman : Professor M. Halaunbrenne (*Poland*) ; " Teaching of mathematics ", Professor J. P. Mathieu (*France*). Chairman : Dr. J. Topping (*U.K.*).

August 3

" The training of teachers ", Professor B. Rosen (*Belgium*) ; " Postgraduate training of physicists ", Dr. C. G. Suits (*U.S.A.*). Chairman : Professor P. Fleury (*France*).

August 4

" The use of films and television in the teaching of physics ", Professor Harvey White (*U.S.A.*) and Dr. W. Kelly (*U.S.A.*). Chairman : Professor H. Staub (*Switzerland*).

Films were shown from 9–9.30 a.m. and from 2–5.30 p.m. on most days.

LIST OF SUPPORTING PAPERS

1. " Co-operative effort toward the improvement of physics education in the United States of America ", W. C. Kelly (*U.S.A.*).
2. " The American Association of Physics Teachers : its role in aiding and improving physics education ", L. O. Olsen (*U.S.A.*).
3. " The influence of Professional Institutions on education in Great Britain ", N. Clarke (*U.K.*).
4. " L'Appreciation des Aptitudes et l'Orientation des Etudiants ", P. M. Duffieux and Ch. Bried (*France*).
5. " Les Methodes de L'enseignement Superieur ", J. P. Mathieu and M. Soutif (*France*).
6. " Selection for university education ", G. K. T. Conn (*U.K.*).
7. " Physical Olympiads—scientific competition between the pupils of the higher classes in the secondary schools as a method of elimination and directing of the most talented pupils to study of physics ", M. Halaunbrenner (*Poland*).
8. " Selection of students for university courses ", Shiro Takagi and Bun-ichi Hanazaki (*Japan*).
9. "Physics in general education", Yoshinobu Kakiuchi (*Japan*).
10. " The place of practical work in school physics teaching ", H. F. Boulind (*U.K.*).
11. " Some features of practical classes in British universities ", J. G. Wilson (*U.K.*).
12. "L'enseignement de l'Optique", P. Fleury (*France*).
13. " Introduction of indivisibility of matter and electricity at an early stage of senior high school teaching ", Yoshio Fujioka and Tatsuoki Mayajima (*Japan*).
14. " Physics education as a cultural course in Japanese universities ", Yoshio Miduno (*Japan*).
15. " L'Enseignement de la physique au Niveau du second degre ", R. Dechene and M. Eurin (*France*).
16. " Post-war experience in Japan in physics education at high school level ", Haruo Ootuka (*Japan*).
17. " Physics experiments in upper secondary schools ", Ichi Yoshimoto, Kiyoshi Fujii, Jiro Hasegawa (*Japan*).
18. " Physics education in technical upper secondary schools in Japan ", Motoichi Tada (*Japan*).
19. " Problems and physics exercises in upper secondary schools in Japan ", Shoji Shinohara and Hitoshi Kagawa (*Japan*).
20. " Present state of and some problems in physics education in Japanese upper secondary schools ", Hideo Ohashi and Seizo Otsuka (*Japan*).
21. " Quelques principes methodologiques pour l'enseignement de la physique au niveau secondaire superieur ", Hugo Saini (*Switzerland*).
22. " Au degre secondaire, l'enseignement de la physique doit suivre de plus pres l'evolution scientifique. Comment la Confederation et les Cantons suisses peuvent-ils contribuer a attiendre ce but ? " M. E. Vaterlaus (*Switzerland*).
23. " The organization of experimental work in Turkish universities and technical institutions ", M. Santur (*Turkey*).
24. " The basic physics course at the Swiss universities ", H. H. Staub (*Switzerland*).
25. " The training of physicists in South Africa ", W. Schaffer (*South Africa*).
26. " Present status and some problems of physics education in the graduate school in Japan ", Moriso Hirata, Mitsuo Miwa, and Haruo Ootuka (*Japan.*)
27. " Physics education for engineers in Japanese universities ", Yasumasa Tani (*Japan*).
28. " Developments in technical and technological education with special regard to physics ", J. Topping (*U.K.*).
29. " Types divers d'Ingenieurs physiciens et leur formation ", G. A. Boutry and J. C. Simon (*France*).
30. " Requirements upon university physics education from the standpoint of industry ", T. Harada (*Japan*).
31. " On the rearrangement of physics courses in higher technical education ", U. Korhonen (*Finland*).
32. " The methodical centres for improvement of the methods of teaching physics and for raising the scientific level of the secondary school teachers ", M. Halaunbrenner (*Poland*).
33. " Sur la collaboration entre les professeurs de l'enseignement secondaire et l'universite ", B. Rosen (*Belgium*).
34. " Training of physics teachers in Japanese universities ", Akira Harasima, Yoshio Ikemoto and Donald C. Worth (*Japan*).
35. " How to prepare science teachers for junior high schools ", Ali Haydar Caglayan (*Turkey*).
36. " The advantages of television in the teaching of physics ", Harvey E. White (*U.S.A.*).
37. " Fortbildungswochene als mittler neur Forschungesergbnisse ", Franziska Seidl (*Austria*).
38. " The visiting scientist's program and the Institutes for teachers in U.S.A. ", J. W. Buchta (*U.S.A.*).
39. " Undergraduate physics education in Japan ", Tosiro Kinbara, Akira Harasima, and Donald C. Worth (*Japan*).
40. " The teaching of physics in schools ", O.E.E.C.
41. " Secondary school physics program of the Physical Science Study Committee, Progress Report 1959 ". (*U.S.A.*)
42. " School systems in O.E.E.C. countries ".
43. " The teaching of mathematics to physicists ", Institute of Physics, London. (*U.K.*).
44. " The postgraduate training of physicists in British universities ", The Institute of Physics and The Physical Society, London. (*U.K.*).

Notes and News

Staff and Administration

The preparatory work leading up to the amalgamation of the Institute and Society placed a heavy burden on the staffs of the two bodies, and the Council of the Society and the Board of the Institute have recorded their appreciation of the way this has been borne over the past two years.

Now that the amalgamation has taken place, the consequent reorganization is making the work of the staff still more arduous. The integration of the work of the various committees of the two bodies, of the membership records and accounts, the preparation of new literature, the transfer of leases and contracts and a legion of other detailed matters all have to receive attention. Good progress is being made but it will inevitably be some months before the organization is fully efficient. Members will, I am sure, be indulgent during this transition period.

Priority must, of course, be given to the basic activities—the publications, scientific meetings (including those of the Branches and Groups), the exhibition, and the educational and professional work. This means that some other things that should be done will have to be postponed for a time—for instance, the preparation of a new list of members now numbering nearly ten thousand.

I shall always welcome comments and criticisms from members, which will assist us to give them the best service possible with the limited resources available.

C. G. Wynne,

Honorary Secretary.

Use of membership abbreviations

Enquiries have been received from members about the correct abbreviations indicating their grade of membership in the amalgamated body.

Only the professional grades, Fellow of The Institute of Physics (F.Inst.P.), Associate of The Institute of Physics (A.Inst.P.) and Graduate of The Institute of Physics (Grad.Inst.P.) may use abbreviations. Those who are Fellows of The Physical Society only, are not entitled to the use of any letters after their names and may not use membership in this grade to indicate professional status.

This position is precisely as before amalgamation.

Addresses for communications

All the editorial work of the Institute and Society, with the exception of the editing of the *Bulletin*, is now concentrated at 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Manuscripts and all correspondence relating to the editorial content of the *Journal of Scientific Instruments*, the *British Journal of Applied Physics* and the *Proceedings of The Physical Society* should be sent to that address. All other correspondence for the Institute and Society, including orders for the above publications, should be sent to 47 Belgrave Square, London, S.W.1.

Laboratory and Workshop Notes, 1956-58

Dr. Ruth Lang has compiled a fifth volume of laboratory and workshop notes from the *Journal of Scientific Instruments*, and this is to be published by Edward Arnold (Publishers) Ltd. at the end of next month. Members are entitled to purchase copies at a reduced price of 31s. 6d., including postage (retail price 40s.), prior to publication and a form for this purpose is enclosed with this *Bulletin*. Members in the United Kingdom wishing to take advantage of the reduced rate must return this to Headquarters at 47 Belgrave Square, London, S.W.1, by October 15, and those living abroad are asked to return it as soon as possible. As the royalties from this book will be donated to the Benevolent Fund, as have those of the four earlier similar volumes, members are specially invited to do what they can to ensure that this new volume is purchased in large numbers.

Stress Analysis Group conference

The Stress Analysis Group is arranging a conference at Southampton University from April 24-28, 1961. The main topic of the conference will be "The Mechanism of Rupture" and papers are being sought from people working on widely different materials. Anyone wishing to submit a contribution should let the Honorary Secretary of the Group, Mr. C. D. Pomeroy, F.Inst.P., Coal Mechanics Branch, Mining Research Establishment, Worton Hall, Worton Road, Isleworth, Middlesex, have the title and a short summary of the paper by the end of September. Contributions should not exceed 30 minutes' duration.

D.S.I.R. Grants

The Department of Scientific and Industrial Research has issued through the Stationery Office two booklets giving full details of grants available for research. The first, *D.S.I.R. Studentship and Fellowship* (1s. 6d.) will be of interest mainly to the younger graduate while the other, *D.S.I.R. Research Grants* (1s. 3d.) is concerned with grants to those of acknowledged standing in their subject.

D.S.I.R. Report for 1959

This commendably brief report contains some items which will be of special interest to members, in addition to the usual appendices giving the names of the members of the various committees, of the staff at the different stations and establishments and containing a good deal of statistical and financial information.

The report has three central themes. The first concerns the steady expansion of the Department's work, particularly in the aid it is giving for special researches and postgraduate training. The second is the consolidation of the changes made in the functions and organization of some of the research stations. The third concerns co-operation between the various research organizations with which the Department is concerned.

In the year 1958-9, 295 grants were made with the total value of £2,232,000, compared with 119 awards totalling £445,000 in the previous year. Fifty-two of the grants were for nuclear physics and 14 for human sciences. The postgraduate training awards have also increased and in October 1959, there were 2,144 of these compared with 1,681 a year earlier. The number of advanced course studentships and research fellowships awarded has also increased substantially. The report records that the Department now has a staff to keep it in close personal contact with the heads of science and technology departments in the universities and colleges and to ensure that the grants are distributed in the best possible way. The report states "there is evidence that the universities and colleges welcome these closer relations and that regular visits by the Department's staff will make for mutual understanding and for smooth operation of the scheme."

The Research Council has completed its survey of present and projected research at the Department's research stations, which has led to it reconsidering the broad aims and functions of the stations as a whole and to redefine their terms of reference clearly and in relation to modern needs. The Directors of the stations will use this information to help them guide the expansion of their activities along sound lines.

The British Scientific Instrument Research Association has recently built up a program of research on industrial instruments for the benefits of both makers and large-scale users and has also instituted, in co-operation with the Scientific Instrument Manufacturers' Association, a service for answering enquiries about instruments.

The Council is anxious that the Department's research stations and the grant-aided Research Associations shall enjoy close and constructive relations with the universities and colleges of technology and has reviewed the situation to see where the various links can be strengthened. In particular, it is suggested that more use can be made of consultants and students in the vacations, and a number of other suggestions for closer co-operation are made.

The report concludes with a reference to the Council's major preoccupations in future years which it says will be " a critical watch on events, with action where necessary to fill gaps and make good deficiencies ".

Reviews of Books

A BRIEF HISTORY OF THE ROYAL SOCIETY

By E. N. da C. Andrade

London : The Royal Society. Pp. 28. Price 10s. 6d.

This booklet is a little masterpiece of its kind. It cannot have been easy to give a worthwhile impression of The Royal Society in less than thirty pages. Yet everything essential is there, and beautifully presented : on a broad front it may well prove one of the most enduring products of the July 1960 Celebrations.

The most important lesson to be learnt—an encouraging one for lesser folk—is the way in which the Society has progressed from being little more (at times) than an assemblage of social worthies to becoming the most distinguished body of men and women devoted to science in this country, and perhaps in the world. This gradual transition must have demanded a degree of foresight and courage on the part of Councils (and reformers) difficult to overestimate. With the present regulations, about one in twelve of the candidates is successful at the annual election of Fellows. Even so, the total Fellowship is of the order of 600, and demonstrates how powerful a factor science has become in the national life. Sometimes people find it difficult to believe that our leading citadel of scientific learning is an independent institution, a private corporation, administering Government grants but essentially the property of the Fellows, and, in the last resort, ruled solely by their decisions.

A point of great significance which Professor Andrade makes is the impartial view which the Society takes of the position of its foreign *members* (not *Fellows*), even in periods of armed conflict. There were no ejections—though such a course was suggested—during the war of 1914-18, and none were even mooted in World War II. In this way the Royal Society may well have done something towards the healing of the Nations. As a matter of fact, Planck attended the Newton Celebrations in 1946, and Von Laue was elected a foreign member in 1949. Much international goodwill was also manifested in the Geophysical Year 1957-8.

All in all, the Royal Society is a typically British Institution, its course determined more by events and circumstances than by conscious planning. Its motto " Nullius in Verba " proclaims its intellectual freedom, and its passion for truth whatever the consequences.

Anyone who is fortunate enough to become possessed of this *Brief History* will have something not only very inspiring to read, but also something aesthetically pleasing in format and worthy of a great historical occasion, namely the Royal Society's three-hundredth birthday.

F. I. G. Rawlins.

FROM NUCLEUS TO UNIVERSE

Edited by S. T. Butler and H. Messel

Sydney: Shakespeare Head Press Pty Ltd. Pp. 335. Price 84s.

This book contains a series of lectures given in a ten-day course for science teachers at the University of Sydney. For the participants it will provide a quite excellent record of what must have been a particularly stimulating experience, and Professors Butler and Messel and their colleagues are to be congratulated on the initiative which brought together so strong a lecturing team.

For other readers, books of this kind are not normally very satisfactory : the relevance of one chapter for another and variations of standards among them become much more important, and in effect mean that a particular reader frequently gets the book for a part only of the whole. The difficulty applies to some sections of the present book, but it is unusual insofar as a series of lectures by Gamow on the Universe and its Origin, by Bok on the Observational Basis for Stellar Evolution, by Gold on the Origin of the Solar System and by Day on the Interior of the Earth form a coherent group of well-related topics treated at a very uniform level. Indeed, these sections form one of the most readable summaries of the field which they cover now available. Since they occupy nearly half of the book, and since they are supported by other sections (Twiss on Stellar Interferometry, Martyn on Space Physics, McCusker on Cosmic Radiation and Rathgeber on the Van Allen Radiation) of related interest although more specialized and detailed in treatment, a great part of the book centres around connected themes treated in a manner at once authoritative and interesting.

It will be clear that despite the title, this is essentially a book about geophysics and astrophysics ; an introductory chapter on atomic and nuclear physics and a second on thermonuclear physics occupy relatively little space and have no close connection with the main material.

The price which for whatever reason appears to be quite out of line with what one expects for a volume of this size and character, is likely to keep sales in the United Kingdom at a very low level.

J. G. Wilson.

ELEMENTS OF SOLID STATE THEORY

By G. H. Wannier

London: Cambridge University Press. Pp. vi + 270. Price 35s.

A book of this sort has been badly needed for some time. There are several good books on solid state physics which rest on an account of experimental fact, with the simplest theory clearly explained but all the harder proofs referred to the advanced theoretical texts. Equally, there are several good books on solid state theory which are standard equipment for the research worker but which are not very easily approached even by the experimental research student. *Quantum theory of solids*, by Peierls, bridged most of the gap, but is still rather hard even for final year undergraduates.

This new book by Wannier exactly meets the need for a text taking solid state theory from final year undergraduate to elementary post-graduate level. Some important topics are omitted, but these—interaction with radiation, thermal conduction and expansion, superconduction—are the topics whose theory is in any case too hard to be tackled seriously in an undergraduate class. These omissions are much more than compensated by the thorough discussion of simple but fundamental results commonly glossed over in books on experiment or on advanced theory. The careful reader who works through not only text but examples will have an admirable preparation for serious work in solid state theory.

Recent fundamental work such as that of Van Hove on the frequency distributions of lattice vibrations, and Yang and Lee's paper on the lattice gas, is included and discussed. The references, mainly to review articles, at the ends of the chapters, will prepare the reader for the most recent literature or for the harder texts. A comparably up to date survey of the review literature on experimental work would have been very useful as a supplement, though any extensive discussion of experimental results would probably have increased the price of the book more than its value.

I strongly recommend this book.

G. Wyllie.

SELECTED LECTURES IN MODERN PHYSICS

Edited by H. Messel

London : MacMillan & Co., Ltd. Pp. vii + 328. Price 30s.

The lectures which make up this book were given at a summer school for science teachers at the University of Sydney during January, 1958. The lectures have been published to " help to bring up-to-date the many science teachers who could not attend."

The book falls naturally into two parts. The first eight chapters, comprising about half the book, deal with nuclear and particle physics. Written for the non-specialist in a very readable style—very few mathematical symbols appear—the lectures nevertheless contain a surprising amount of solid information. Even the most out-of-date science teacher will have a fairly good idea of how the nuclear physicist looks at his world after reading this part of the book. Few books escape without a misprint or two. A very misleading mistake appears several times on p. 37 where the output of a transformer is described as " 100 keV, 200 cycle."

The second half of the book probably suffers from the amount of space devoted to nuclear physics. Many subjects are treated briefly and the level is rather uneven. Radioastronomy, space travel and relativity, transistors and isotopes in medicine are all included. Thermodynamics is represented by two lectures, one on temperature and the other on superfluids. The latter is correctly classed as modern physics but the former has a slightly old-fashioned flavour.

For science teachers and others wanting a readable account of modern ideas on nuclear physics this book can be recommended. They will find it gives less complete coverage of other subjects.

J. M. Valentine.

WAVE PROPAGATION IN A RANDOM MEDIUM

By Lev. A. Chernov

London: McGraw-Hill Publishing Co. Ltd. Pp. viii + 168. Price 58s.

This book has been translated from the Russian original by R. A. Silverman ; its contents would have been more clearly indicated if the literal translation of the Russian title had been used, viz., Wave Propagation in a Medium with Random Inhomogeneities. The work includes an investigation of the effect of refractive index fluctuations on the propagation of acoustic and electromagnetic waves through the troposphere and the ocean. Particular attention is given to the amplitude and phase fluctuations of a plane wave as a function of the distance penetrated, and their correlation, and to the effect of refractive index fluctuations on image formation in focusing systems.

In the first of three Parts ray approximations are used. In Part II the diffraction theory is employed while Part III deals with the effect on focusing systems mentioned above.

Part I introduces the statistical characteristics of the medium and develops the angular distribution of rays using the Einstein-Fokker-Kolmogorov equation. In Part II the acoustic wave equation is derived for an inhomogeneous medium and then the scattering produced by inhomogeneities is examined, together with the resulting attenuation of an acoustic bundle. The remaining, greater portion of this part is devoted to fluctuations. The basic formulae for amplitude and phase fluctuations are derived by the small perturbations and Rytov methods, and the regions of large, small and intermediate values of the ratio of the size of the first Fresnel zone to the scale of the inhomogeneities are considered. A detailed analysis of the correlation of fluctuations ends with a comparison of the fluctuation theory developed by the author, with experimental results in the fields of sound propagation in the atmosphere and deep water, and the twinkling of stars. Part III considers the mean distribution and the distribution of fluctuations in an optical diffracted image, not restricted to small fluctuations.

The scope of the book should be clear from the above. The material is well presented, apart from one or two minor irritations in notation. Some mathematical derivations are sensibly deferred to appendices. Approximately sixty references are given and about half of these are to Russian journals.

R. G. Harlow.

INTRODUCTION TO SOLIDS

By L. V. Azaroff

London: McGraw-Hill Publishing Co. Ltd. Pp. xiv + 460. Price 74s.

This text is a welcome addition to the books which can be recommended for use by advanced students. The approach used is rather different from those used by Kittel, Dekker, Cusack, and others, and the emphasis throughout is based on crystal structure, symmetry, and periodicity. Sufficient elementary quantum mechanics is employed to lead to band concepts, and statistical thermodynamics is used where necessary, but in general the mathematical treatments will be readily understood by the student who regards himself as an " experimentalist." The first four chapters deal with basic crystallography and atomic packing arrangements. The diagrams in this section are among the best the reviewer has seen. A form of shaded printing gives a 3-D effect in many of the diagrams used to illustrate packing arrangements. Imperfections, mechanical properties, crystal growth, transformations, and atomic bonding are all treated and the remainder of the book is devoted to properties and structures of metals, semiconductors, and insulators.

At the end of each chapter are numerous questions, both qualitative and quantitative, which enable one to judge whether the previous chapter has been studied to advantage. The level of the book is truly introductory and the treatment throughout is even. References for further reading are given at the end of each chapter. The book could be well read with advantage by teachers as well as students.

C. A. Hogarth.

VISTAS IN ASTRONOMY — VOLUME 3

Edited by A. Beer

Oxford : Pergamon Press Ltd. Pp. vii + 345. Price 120s.

A dozen years ago Dr. Arthur Beer of Cambridge Observatory undertook to collect a " Festschrift " in honour of the birthday of F. J. M. Stratton, now retired from the Cambridge Professorship of Astrophysics, and one of the prime organizers of international astronomical co-operation. The enterprise took more years than expected to complete, a vast two-volume set of essays finally emerging, by more than a hundred astronomers from all over the world. The instruction to all authors was to give a new and original summary of some live controversy in which they were playing an active part ; so the result was a kind of encyclopedia of astronomical topics in non-alphabetic order. But the success of this mode of presenting the astronomy of a fast-moving generation has led to the idea of continuing its usefulness. So the present book (smaller than its predecessors) is " Volume Three " and more may arrive in due course. It contains only 21 papers this time, from England, U.S.A., U.S.S.R., and parts of Europe.

The topics include electronic computors in astronomy; observational tests of relativity ; artificial satellites ; magnetic fields in the formation of a star ; mechanisms of spectral line excitation in stellar atmospheres ; recent comets ; the dynamics of galactic structure ; Aurora Borealis ; photometry with Schmidt telescopes.

It is evident that the aim has been to avoid topics discussed in the earlier volumes unless opinions therein are changing rapidly.

Martin Johnson.

PRINCIPLES OF ELECTRICITY AND MAGNETISM

By E. M. Pugh and E. W. Pugh

Massachusetts : Addison Wesley Publishing Inc. Pp. xi + 430. Price 49s.

FOUNDATIONS OF ELECTROMAGNETIC THEORY

By J. R. Reitz and Frederick J. Milford

Massachusetts : Addison Wesley Publishing Inc. Pp. xi + 386. Price 49s.

These two books will be reviewed together because they naturally contain much common material and come from the same publishers. The former appears to be a family affair and, it seems, page for page is slightly better value for money. However, certain differences between these two works are apparent.

Both begin with fairly brief treatments of units and then proceed via electrostatics to the theory of dielectrics, steady currents, electromagnetic induction, magnetic properties of matter (Reitz and Milford give more on this and their treatment is rather better), alternating current theory and electromagnetic radiation. Reitz and Milford interpose a chapter on the physics of plasmas and two chapters on Maxwell's equations and applications thereof. They also conclude with a chapter on electrodynamics, i.e. the field of a uniformly moving point charge and the radiation from accelerated point charges, etc.

Both works have been prepared with great care. My personal preference is for Reitz and Milford because they include rather more physical applications of what is essentially a basic theoretical treatment, e.g. the domain theory and properties of magnetic materials, although this is not to say that Pugh and Pugh ignore these matters completely for they devote one chapter to an account of magnetic materials. Vectors of course are used extensively in both books and their standard is roughly that of Final Year physics or electrical engineering University courses, although the latter would certainly demand specialization in certain aspects of the work, for example in wave propagation in bounded media which is treated fairly briefly in both books but perhaps rather better by Pugh and Pugh.

The electromagnetic treatment of plasmas by Reitz and Milford is of special interest because it is unusual to find this material in an undergraduate text. It is very well done.

Any reviewer is bound to wonder why a publisher should issue two closely similar books at the same time. Intoxicated perhaps by the wine of private enterprise he may feel encouraged to support different educational establishments in this way, each backing its own book perhaps to the extent of a few hundred copies a year as a students' text, but the effect on the general student world is apt to be confusing. Presumably very few undergraduates, at least in Britain, would feel able or willing to purchase both books and it is at least comforting that they are both of a high standard. However they commit the same sin, for such it is according to a highly expert colleague who is a purist, particularly in matters of electromagnetism, and which is usual in works on the present subject. This is the infliction of electrostatics on students for the purpose of introducing inverse square forces, etc., and related matters (units) instead of starting with the combination of a current-carrying conductor and a magnetic field. Starting with Coulomb's law in its rationalized m.k.s. form necessitates a confusing discussion of units and dimensions and ignores the fact that electricity and magnetism are parts of a whole.

Another general problem, philosophical and utilitarian arises. To what extent should authors produce expensive students' texts when, I believe, they are so infrequently read " from cover to cover " ? Is there not a strong case for the preparation of less ambitious and detailed books for general undergraduate use giving the essential basic theory ? Such limited reading can always be supplemented by those wishing to do so but suitable books of this kind are rare apart from notably exceptional series of monographs which are often more advanced than is necessary for strictly undergraduate use.

J. D. CRAGGS.

INTRODUCTION TO NEUTRON PHYSICS

By L. F. Curtiss

London: D. van Nostrand Co. Ltd. Pp. xi + 380. Price 73s.

This book would be more aptly entitled ***Introduction to Experimental Neutron Physics***, as it is the author's stated intention to introduce the student to " the more basic features of the experimental science of the neutron," and the volume is largely devoted to experimental techniques. The techniques described are related to the detection of neutrons, neutron sources and their calibration, spectrometers and monochromators and neutron diffraction. These experimental matters are handled with confidence. However, an early chapter which describes the reactions in which the neutron participates is uneven and unsatisfactory in some respects as, for example, the Breit-Wigner formula is discussed at some length without indicating the conditions under which a cross-section may follow the 1/v law. In addition, the subject of fission is dismissed in two pages of text and three diagrams which is surely inadequate for a volume whose dust-cover claims that it will be of interest to all those now working with nuclear reactors. The selection of topics may also be queried, as there is considerable discussion of the rather specialized subjects of neutron source manufacture and calibration, but there is no account of any of the large number of experiments concerned with the neutron physics of reactors.

In conclusion, the author has performed a valuable service in describing a variety of techniques and apparatus, and the book may be recommended to both undergraduates and postgraduate students who want a review of experimental methods associated with the study of neutrons. It is of little interest to those concerned with the physics of nuclear reactors.

W. G. DAVEY.

GREAT EXPERIMENTS IN PHYSICS

Edited by Morris H. Shamos

New York : Henry Holt & Co. Pp. viii + 370. Price $4.40.

The author of this book, like its reviewer, believes that the study of the history of science forms a valuable basis for the presentation of scientific principles to those who are studying science as an element of a liberal education. The author states that this book " was developed mainly for use by liberal arts students in a new laboratory physics course at Washington Square College (of New York University)," and " traces the development of physical principles by a detailed study of a number of the most telling experiments in physics." The author's method is to select nineteen experiments important in the evolution of physics, and to reproduce the original papers, or translations of them, each supplemented by marginal notes and introduced by a biographical note of the paper's author. The experiments are well chosen and range from Galileo on accelerated motion, through (selecting at random) Newton on the laws of motion, Young on interference, Faraday on electromagnetic induction, Hertz on electromagnetic waves and Einstein on the photoelectric effect, to Chadwick on the neutron. An appendix contains five theoretical and more difficult papers which the author includes as being essential for an understanding of modern ideas (Maxwell on the electromagnetic field, Planck on the quantum hypothesis, Einstein on relativity, Bohr on the hydrogen atom, and Compton on his effect). The reviewer would be surprised if " liberal arts students," in this country at least, would make very much of this collection ; but he can strongly recommend it as general reading for any physicist, young or old, with or without a special interest in the history of science.

D. H. FOLLETT.

THE WORLD AROUND US

Edited by Sir Graham Sutton

London: The English Universities Press Ltd. Pp. vi + 122. Price 16s.

This little book is a collection of six essays by well-known experts based upon the Christmas Lectures for young people given at the Royal Institution during the Christmas holidays 1958/59. The lectures were planned by Sir Lawrence Bragg to give the audience some idea of the purpose of the International Geophysical Year and, furthermore to show something of the modern scientific approach to the particular topics. These are, I the Ionosphere, II, the Earth's Magnetism, III, Exploration of the Upper Atmosphere, IV, the Lower Atmosphere and its Weather, V, the Sea and its Problems, VI, the Antarctic. There is no space for a detailed appraisal of each essay, nor is such needed for all are excellent. Here and there the scientific knowledge assumed to be possessed by the reader is beyond that of the average VIth form pupil, but the essays are very readable and do incite to further study. The book can be strongly recommended to all scientists who are not in touch with these special topics.

The production is excellent: the paper, the illustrations and the general appearance deserve praise. It forms another addition to the books of the Christmas lectures and will take a worthy place with its famous predecessors.

W. ASHHURST.

Forthcoming Institute and Society Meetings

The following is the list of Institute and Society meetings so far arranged for the first half of the 1960-1961 session. In some cases arrangements are provisional. Fuller details for each meeting will be sent in due course to the members of the Branch or Group concerned and may be obtained by other members of the Institute and Society on application to the Secretary. Where it is indicated that registration is necessary early application should be made.

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Sept. 8	**London** Imperial College		Symposium on **Sound propagation in the atmosphere**	9.30 a.m. to 5.45 p.m.	Acoustics
Sept. 14	**Glasgow** The University	Professor C. F. Powell, F.R.S. *(University of Bristol)*	**The Rutherford Lecture** on **Studies of nuclear disintegrations at very high energies** (in conjunction with the conference on nuclear physics)	8.30 p.m.	
Sept. 14 and 15	**Glasgow** The University		Conference on **Nuclear physics** Closing date was August 23, 1960, but any enquiries should be addressed to Mr. R. Giles, the Nuclear Physics Conference Secretary, Natural Philosophy Department, The University, Glasgow, W.2.		
Sept. 19	**Manchester** College of Science and Technology	Dr. K. W. Todd *(A.E.I., Manchester, Ltd.)*	**Optical techniques for the study of air flow**	7.00 p.m.	Manchester and District
Sept. 22	**Coventry** Courtaulds Ltd.		Visit to the Acetate and Synthetic Fibres Laboratory, followed by a talk. Registration for this visit is necessary		Midland
Sept. 22	**Reading** The University	Professor R. V. Jones, C.B., C.B.E., F.Inst.P. *(University of Aberdeen)*	Presentation of the Duddell Medal to Professor Jones who will give a lecture on **Some developments of the optical lever**	5.00 p.m.	
Sept. 22 and 23	**Reading** The University		Conference on **Diamond physics** Registration is necessary and enquiries should be addressed to Dr. C. D. Clark, J. J. Thomson Physical Laboratory, The University, Reading.		
Sept. 22 to 24	**Cheltenham**		Conference on **The theory and practice of ultrasonic inspection** Registration for this Conference is necessary.		Non-Destructive Testing jointly with S.O.N.D.E. and N.D.T.S.
Sept. 28	**Watford** Building Research Station		Visit to the Building Research Station Registration for this visit is necessary.	11.00 a.m.	Stress Analysis
Sept. 30	**London** Headquarters		One-day meeting on **Ion sources** Registration for this meeting is necessary.	10.30 a.m.	Electronics

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Oct. 5	**London** Institute of Ophthalmology	Dr. R. Weale Dr. S. J. J. Clarke	**Extra-foveal colour vision** **Extra-foveal colour metrics**	3.00 p.m.	Colour
Oct. 6	**Ewell, Surrey** Ewell County Technical College	Dr. J. S. Forrest, F.Inst.P. (*Research Laboratories, Central Electricity Authority, Leatherhead*)	**Physics and chemistry in electrical research**	7.00 p.m.	London and Home Counties jointly with the College Faraday Society
Oct. 6	**Seascale** County School	Professor G. D. Rochester, F.Inst.P., F.R.S. (*University of Durham*)	**Recent work on the strange particles of physics**	7.00 p.m.	North-Eastern
Oct. 12	**London** Headquarters		**Reports on the 7th International Conference on Low Temperature Physics, Toronto, and the Boulder Cyrogenic Engineering Congress.**	4.00 p.m.	Low Temperature
Oct. 13	**Middlesbrough** Cleveland Scientific and Technical Institute	Mr. H. Kenney, M.I.Mech.E. (*Imperial Chemical Industries Ltd., Billingham*)	**The errors of instruments—their study and importance**	6.30 p.m.	North-Eastern jointly with the Society of Instrument Technology
Oct. 13	**Liverpool** The University	Dr. A. Baines (*Imperial Chemical Industries Ltd., Widnes*)	**The development of electronic computer applications**	7.00 p.m.	Liverpool and North Wales
Oct. 14	**London** Headquarters		**Mass spectrometry**	All-day meeting	Applied Spectroscopy
			Registration for this meeting is necessary.		
Oct. 14	**Bristol** The University	Professor R. W. Ditchburn, F.Inst.P. (*University of Reading*)	**Problems of information and control in the visual system**	7.00 p.m.	South Western
Oct. 21	**London** School of Pharmacy		**Recording ultraviolet spectrophotometers** (the time to be announced later)		Optical jointly with Photo-electric Spectrometry Group
Oct. 18		Dr. C. Hilsum, A.Inst.P. (*Services Electronics Research Laboratory, Baldock*)	**Applications of galvanomagnetic effects in semiconductors**	5.30 p.m.	Electronics
Oct. 19	**London** Headquarters	Dr. N. Thompson, F.Inst.P. (*University of Bristol*)	**Admission of physics students to universities**	6.00 p.m.	Education
Oct. 21	**London** Headquarters	Dr. C. A. Mann, A.Inst.P. (*United Kingdom Atomic Energy Authority, Preston*)	Group Annual General Meeting followed by a lecture on **Some aspects of leak testing in theory and practice**	6.00 p.m.	Non-Destructive Testing
Oct. 21	**Cardiff** University College	Dr. H. J. Goldsmid, F.Inst.P. (*Research Laboratories of The General Electric Co. Ltd., Wembley*)	**Modern developments in thermoelectricity**	6.15 p.m.	South Wales
Oct. 24	**Manchester** The University	Professor W. H. G. Armytage (*University of Sheffield*)	**The endless frontier**	7.00 p.m.	Manchester and District
Oct. 26	**London** Headquarters		Half-day meeting on **New techniques in stress analysis**	2.30 p.m.	Stress Analysis
			Registration for this meeting is necessary.		
Oct. 26	**Birmingham** College of Advanced Technology		Annual General Meeting, followed by a lecture. (details to be announced later)	6.30 p.m.	Midland
Oct. 28	**London** Headquarters		Branch **At home**	7.30 p.m.	London and Home Counties
			Registration for this event is necessary.		
Nov. 2	**Glasgow** The University	Professor D. J. E. Ingram, F.Inst.P. (*University College of North Staffordshire, Keele*)	**Electron spin resonance**	7.15 p.m.	Scottish
Nov. 2	**Manchester** College of Science and Technology	Dr. C. A. Taylor, F.Inst.P. (*Manchester College of Science and Technology*)	**Recent developments in optical transform techniques**	7.00 p.m.	X-Ray Analysis

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Nov. 3	**St. Andrews** The University	Professor D. J. E. Ingram, F.Inst.P. (*University College of North Staffordshire, Keele*)	**Electron spin resonance**	5.00 p.m.	Scottish
Nov. 4	**Aberdeen** The University	Professor D. J. E. Ingram, F.Inst.P. (*University College of North Staffordshire, Keele*)	**Electron spin resonance**	7.30 p.m.	Scottish
Nov. 4	**Exeter** The University	Professor C. W. Allen, (*University College, London*)	**Astrophysical uses of spectroscopy**	5.30 p.m.	South Western
Nov. 9	**Leeds** The University	Dr. B J. Mason (*Imperial College of Science and Technology, London*)	**The generation of electricity in thunderstorms**	5.00 p.m.	Yorkshire
Nov. 9	**London** Imperial College	Mr. L. B. Happé Mr. J. Vickers	**Visual assessment of colour ciné films** **Assessment of photographic colour prints**	3.00 p.m.	Colour
Nov. 10	**Liverpool** The University	Professor W. V. Mayneord, C.B.E., F.Inst.P. (*Institute of Cancer Research, London*)	**The natural and artificial radioactivity among which we live**	7.00 p.m.	Liverpool and North Wales
Nov. 11	**London** Headquarters	Mr. F. R. Bareham, Dr. J. Blitz, Dr. R. W. G. Hazlett, F.Inst.P., Mr. V. J. Upton	A colloquium on **The principles and practice of eddy current testing**	6.00 p.m.	Non-Destructive Testing
Nov. 11	**London** Royal Microscopical Society		One-day meeting including the Group Annual General Meeting followed by papers on **Some physical aspects of the electron microscope** Registration for this meeting is necessary.		Electron Microscopy
Nov. 15	**London** Headquarters		All-day symposium on **Electronic devices to operate at helium temperatures** Registration for this symposium is necessary.	10.30 a.m.	Electronics jointly with Low Temperature
Nov. 15	**Dundee** The University	Dr. G. A. P. Wyllie, F.Inst.P. (*University of Glasgow*)	**Surgical asepsis, a physical problem**	5.30 p.m.	Scottish
Nov. 15	**Birmingham** Midland Institute	Professor S. Tolansky, F.Inst.P., F.R.S. (*Royal Holloway College, University of London*)	**Optical illusions—their influence in scientific observations**	6.30 p.m.	Midland
Nov. 17	**Bangor** University College	Dr. N. B. Slater (*University of Leeds*)	**Fundamental theory**	5.45 p.m.	Liverpool and North Wales
Nov. 18	**Newport** Newport and Monmouthshire College of Technology	Professor R. W. Ditchburn, F.Inst.P. (*University of Reading*)	**Problems of information and control in the visual system**	6.15 p.m.	South Wales
Nov. 21	**Manchester** College of Science and Technology	Dr. C. A. Taylor, F.Inst.P. (*Manchester College of Science and Technology*)	**A physicist looks at music**	7.00 p.m.	Manchester and District
Nov. 25	**London** Institution of Electrical Engineers		All-day symposium on **New materials of interest to the physicist** Registration for this symposium is necessary.	10.00 a.m.	London and Home Counties
Dec. 5	**Edinburgh** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Low noise amplifiers**	7.15 p.m.	Scottish
Dec. 6	**Glasgow** The University	Dr. R. A. Smith (*Royal Radar Establishment, Malvern*)	**Low noise amplifiers**	7.15 p.m.	Scottish
Dec. 7	**Sheffield** The University	Professor G. F. J. Garlick, F.Inst.P. (*University of Hull*),	**Luminescence and recombination radiation in semiconductors**	5.00 p.m.	Yorkshire
Dec. 7	**London** Headquarters	Mr. N. Clarke, F.Inst.P. (*The Institute of Physics and The Physical Society*)	**The international conference on physics education**	6.00 p.m.	Education
Dec. 7			Subject, speaker, place and time to be announced		Colour

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
Dec. 8	**Liverpool** The University	Dr. L. R. Shepherd (*A.E.E., Winfrith*)	**Dragon project**	7.00 p.m.	Liverpool and North Wales
Dec. 8	**Birmingham** The University	Professor P. B. Moon, F.Inst.P., F.R.S. (*University of Birmingham*)	**X-ray spectroscopy**	6.30 p.m.	Midland
Dec. 9	**London** Headquarters		Subject, speaker and time to be announced		Non-Destructive Testing
Dec. 9	**Newcastle-upon-Tyne** King's College	Dr. O. S. Heavens, F.Inst.P. (*Royal Holloway College, London*)	**Masers in the optical and infra-red regions of the spectrum**	6.15 p.m.	North-Eastern
Dec. 9	**Bristol** The University	Mr. Thorold G. Jones, F.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	**Gem stones**	7.00 p.m.	South-Western
Dec. 12	**Manchester** The University	Professor W. D. Wright (*Imperial College of Science and Technology, London*)	**The problem of the accurate measurement of colour and small colour differences**	7.00 p.m.	Manchester and District
Dec. 12	**Hull** The University	Dr. C. N. W. Litting, F.Inst.P. (*University of Manchester*)	**The physics of computer elements**	5.00 p.m.	Yorkshire
Dec. 14	**London** Headquarters		**The separation of hydrogen and deuterium** (provisional) Speaker and time to be announced.		Low Temperature
Dec. 15	**London** Imperial College		Speaker and subject to be announced	2.30 p.m.	Optical
Dec. 16	**Swansea** University College	Dr. N. Kurti, F.Inst.P., F.R.S. (*Clarendon Laboratory, Oxford*)	Branch Annual General Meeting followed by a lecture on **Recent developments in the millidegree and microdegree absolute temperature range**	5.15 p.m.	South Wales
Dec. 19 and 20	**London** Queen Mary College		Conference on **Statistical Mechanics** (with special reference to irreversible processes) Registration for this conference is necessary.		
Jan. 10 and 11	**Bristol** The University		Conference on **The physics of polymers** Registration for this conference is necessary.		
Jan. 12			Subject, speaker, place and time to be announced.		Liverpool and North Wales
Jan. 13	**London** " Horseshoe Hotel "	Mr. Thorold G. Jones F.Inst.P. (*Atomic Energy Research Establishment, Harwell*)	Dinner meeting followed by an informal address on **Gem stones** Registration for this dinner meeting is necessary.		Non-Destructive Testing
Jan. 16 to 20	**London** Royal Horticultural Society's Halls		**45th Exhibition of scientific instruments and apparatus** Admission is by ticket only, to be sent to members in December.		
Jan. 17 to 19	**London** Royal Horticultural Society's Halls		Exhibition discourses	5.45 p.m. each day	
		Dr. G. E. R. Deacon	**Physics of the oceans**		
		Dr. F. P. Bowden	**The friction and deformation of solids at very high speeds**		
		Mr. F. S. Burt	**Hydrodynamics research** Admission is by ticket only.		
Jan. 18	**London** Headquarters	(to be announced)	Group Annual General Meeting followed by a lecture on **Thermodynamic properties of ^{4}He**	4.00 p.m. 4.30 p.m.	Low Temperature
Jan. 20	**Newport** Newport and Monmouthshire College of Technology	Dr. A. P. Willmore (*University College, London*)	**Astronomical observations from rockets and satellites**	6.15 p.m.	South Wales
Jan. 20	**Bristol** College of Science and Technology	Mr. G. W. Warren, M.B.E., F.Inst.P. (*Research Laboratories of The General Electric Co. Ltd., Wembley*)	**The physicist and the technologist in industry**	7.00 p.m.	South Western
Jan. 23	**London** Headquarters	Dr. E. Eastwood	**Some new applications of radar**	6.00 p.m.	London and Home Counties

Group News

Education Group Summer Outing, 1960

Some 36 members and guests formed the first party to visit the recently opened J. J. Thomson Physical Laboratory of the University of Reading on Saturday, May 28. After coffee, Dr. Rymer welcomed the party in the Small Lecture Theatre and outlined the facilities available in the Laboratories. The visitors were then conducted through the Department in groups, seeing both teaching and research laboratories where work on such topics as semi-conductors and radiation damage was in progress. Lady members of the party were particularly interested in colour changes in diamond. During the tour both the flexibility and range of the services available were apparent.

After lunch in the Buttery the party travelled from Caversham to Henley on a river steamer in glorious summer weather and were pleased to be joined by Professor Ditchburn, by whose courtesy the morning visit had been made, and Mrs. Ditchburn. Members then joined their train at Henley or returned to Reading by coach.

Dr. N. Thompson and Professor R. W. Ditchburn

Applied Spectroscopy Group: Summer Conference at Seascale, Cumberland, on June 16-17, 1960

After an unsuccessful attempt to arrange a Summer Conference at Cambridge in 1958 the Committee's confidence was restored in full measure by the enthusiastic response to our 1960 Conference at Seascale which was attended by over 50 members. As might have been expected, the U.K. Atomic Energy Authority was strongly represented and indeed five of the six papers were presented by Authority staff. They covered a wide range of subjects chosen to suit the tastes of physicists, whether spectroscopists or not, and a summarized account of the papers will be published in the *British Journal of Applied Physics*.

A number of members arrived by the overnight train from Euston in time for breakfast on June 16 and after this the Conference assembled for the first session at the Windscale Club, which was kindly made available for our use by the Club Committee.

The opening paper by Dr. W. M. Lomer (A.E.R.E., Harwell) was entitled " Atomic Physics in a Nuclear Age " and he gave a clear and interesting account of the Mossbauer Effect and took the opportunity of urging his audience not to attempt to draw a line of demarcation between Atomic and Nuclear Physics. This was followed by a paper by Mr. F. J. Woodman (U.K.A.E.A., Windscale) on " The analysis of radioactive materials, with special reference to instrumental methods ". He stressed, *inter alia*, the growing importance of gamma spectrometry as an analytical technique. The final paper in the Session was presented by Mr. R. P. Thorne (U.K.A.E.A., Capenhurst) on " Isotopic analysis, with special reference to Spectroscopic Methods " in which he reviewed various methods and described recent work on the line-shift method using the Fabry-Perot etalon.

In the afternoon Conference members were conducted over the extensive laboratories of the Chemical Services Department and of the Research and Development Branch at Windscale works. These deal with analytical commitments and research problems arising from the Windscale, Calder and Chapel Cross works, and it was interesting to note the high degree of instrumentation employed in the analytical work, much of which had been developed on the spot.

A very successful Conference Dinner was held in the evening at the Scawfell Hotel, attended by 43 members, to which Mr. Tom Tuohy, General Manager of Windscale and Calder Works, was invited as Guest of Honour.

The following morning was devoted to the presentation of the second group of papers. Dr. D. J. Ferret

(Front row) *Mr. F. W. J. Garton, Dr. D. J. Ferret, Mr. F. J. Woodman, Mr. R. P. Thorne, Dr. W. M. Lomer, Dr. A. C. G. Menzies, Dr. W. R. S. Garton, Miss J. M. Rooke, Dr. C. Turner, Miss Smith, Dr. L. E. Bovey.*

(A.E.R.E., Harwell) opened with a paper on " Radioisotopes in Analysis " and included an account of Nuclear Magnetic Resonance work. A paper on " Temperature measurement by Spectroscopy " was then presented by Dr. W. R. S. Garton (Imperial College, London) in which he discussed what was meant by " temperature " in connexion with discharge plasma and gave an account of special types of discharge sources. The last paper of the Conference was by Mr. M. S. W. Webb (U.K.A.E.A., Woolwich) on " The analysis of atmospheric dust with special reference by beryllium monitoring ", at the conclusion of which a live demonstration of the Woolwich Automatic Beryllium Monitor was given by Mr. Webb and his colleague, Mr. R. J. Webb, who was responsible for the design and construction of the instrument. After lunch members were taken on a conducted tour of the Calder Hall power station which greatly impressed even the more sophisticated U.K.A.E.A. members.

All local arrangements for accommodation, visits, transport and entertainment were in the hands of Windscale staff of whom Mr. T. H. Boyd and Mr. B. F. Potts deserve special mention, and the Group Committee wish to express their appreciation to them and to Mr. L. Lawrence.

F. W. J. GARTON.

The Graduateship Examination 1960

THE INSTITUTE's Graduateship Examination was held on May 27–June 2. Written papers were taken at centres in Belfast, Birmingham, London, Paisley, Salford, Sunderland and Swansea ; the practical examination was held in London. In addition one candidate sat for the examination in Ceylon.

One hundred and ninety-three candidates, including five taking the examination in parts, took papers other than the General paper. Details of the sixty-three who were successful in all the papers they were required to take to comply with the academic requirements are given below with the name of the college at which they studied in brackets. Candidates indicated by * were awarded a pass with credit and are entitled to apply for Associateship of The Institute of Physics on the same terms as holders of degrees in physics with first or second class honours.

Adams, Victor William—Farnborough, Hants.
(*Guildford County Technical College*).

Alsop, Michael—Hampton, Middlesex
(*Northampton College of Advanced Technology*)

Arundel, Maurice Leonard—Burgess Hill, Sussex
(*South East London Technical College and Brighton Technical College*)
Bealing, Rex—Reading, Berkshire
(*Reading Technical College and the Borough Polytechnic, London*)
Beeny, Michael Alfred—Salisbury, Wilts.
(*Guildford County Technical College*)
Beeson, Robin Anthony William—Rickmansworth, Herts.
(*Brunel College of Technology, Acton*)
Bird, Derek George—Balham, London
(*South East London Technical College*)
Birtwistle, John Keith—Romiley, Stockport
(*Royal Technical College, Salford*)
Bishop, Max—Amersham, Bucks.
(*Brunel College of Technology, Acton*)
Blanchard, Michael Henry—Heston, Middlesex
(*Brunel College of Technology, Acton*)
Boss, John David—Southbourne, Hants.
(*Bournemouth Municipal College of Technology and Commerce*)

Chase, Rex James—Aberporth, Cardigan
(*Swansea Technical College*)

Conway, Thomas—Knutsford, Cheshire
(*University College of Swansea*)

Day, Brian—Reading, Berks.
(*Northampton College of Advanced Technology*)

Dillon, Garry Bernard—Cheadle, Cheshire
(*Royal Technical College, Salford*)

Dunderdale, Keith Frederick—Wortley, Leeds
(*Leeds College of Technology*)

Gaskell, Waryn Thomas Mogridge—Ightham, Kent
(*Royal Military College of Science, Shrivenham*)

Gelder, Roger—Chadderton, Lancs.
(*University of Liverpool and the Borough Polytechnic, London*)

Gould, Joseph—Melton Mowbray, Leics.
(*Nottingham and District Technical College*)

Hall, Gordon—Basingstoke, Hants.
(*Sunderland Technical College and The Polytechnic, Regent Street, London*)

Jackson, Peter James—Oldham, Lancs.
(*Royal Technical College, Salford*)

Kay, Robert Anthony Smedley—Southport, Lancs.
(*University of Manchester*)

Lawrance, Robert George—Cheadle Hulme, Cheshire
(*University College, Cardiff, and Royal Technical College, Salford*)

Lea, Arnold Trevor—Tolladine, Worcester
(*College of Advanced Technology, Birmingham*)

Longhurst, Charles Edward—Merstham, Surrey
(*Croydon Technical College*)

Major, Rodney Victor—Crawley, Sussex
(*Woolwich Polytechnic and Croydon Technical College*)

*Marshall, Robert—Chertsey, Surrey
(*Guildford County Technical College*)

McDonald, William—Baughurst, Hants.
(*University of St. Andrews*)

Mills, Michael Ernest—Chelmsford, Essex
(*University of Bristol*)

Moir, Jean—Harpurhey, Manchester
(*Royal Technical College, Salford*)

Mossman, Peter—Amersham, Bucks.
(*Brunel College of Technology, Acton*)

Moxon, Michael Charles—Sutton Courtenay, Berks.
(*Oxford College of Technology*)

*O'Mahony, Keith James—Farnborough, Hants.
(*Guildford County Technical College*)

*Parkins, David Walter—Bedford.
(*Northampton College of Advanced Technology*)

Paxton, Brian Harry—Scotsgrove, Oxon.
(*The Polytechnic, Regent Street, and Borough Polytechnic, London*)

Pearce, Leonard John—Boscombe, Bournemouth
(*Bournemouth Municipal College of Technology and Commerce*)

Percival, Neil—Tadley, Hants.
(*University of Manchester and Borough Polytechnic, London*)

Pickles, Eric—Sunbury-on-Thames, Middlesex
(*Guildford County Technical College*)

*Pickup, Rosemary—Garforth, Yorks.
(*Leeds College of Technology*)

Powell, John Robert—Chester
(*University College, Cardiff*)

*Richards, Howard David—Wednesfield, Staffs.
(*Bournemouth Municipal College of Technology and Commerce and College of Advanced Technology, Birmingham*)

Richardson, Michael—Tadley, Hants.
(*University of Reading, and Borough Polytechnic, London*)

Robinson, Christopher Richard—Stafford
(*University of Manchester*)

Robotham, Francis Patrick Joseph—Abingdon, Berks.
(*Sunderland Technical College and Oxford College of Technology*)

Rowntree, Frederick William—Norbury, London
(*Croydon Technical College*)

Rush, David—London
(*University of Birmingham, and The Polytechnic, Regent Street, London*)

Scantlebury, Roger Anthony—Ealing, London
(*Birkbeck College, London*)

Shaw, Norman—Wolverhampton, Staffs.
(*College of Advanced Technology, Birmingham*)

Shelley, Trevor—Cardiff
(*University College, Cardiff*)

Sisitka, Joseph Sandor—Reading, Berks.
(*South East London Technical College*)

Stillwell, John Clifton—Wareham, Dorset
Bournemouth Municipal College of Technology and Commerce)

Tickle, Harry—Warrington, Lancs.
(*Royal Technical College, Salford*)

Turner, Dudley Joseph—Anerley, London
(*Croydon Technical College*)

*Urry, George Frederick—Furness Vale, Cheshire
Blackburn Technical College, and Royal Technical College, Salford)

Vokes, Margaret Anne—Cwmbran, Mon.
(*Technical College of Monmouthshire, Crumlin, and Newport and Monmouthshire College of Technology*)

Wallace, Thomas—Ayr, Scotland
(*The Polytechnic, Regent Street, London*)

Watkins, Donald Lewis—Blackwood, Mon.
(*University College, Cardiff*)

Webb, Ian James—Reading, Berks.
(*Reading Technical College*)

Whitaker, George—Bramcote, Nottingham
(*University of Leeds*)

Whitehouse, Joseph Colin—Blakenhall, Staffs.
(*University of Bristol*)

Whittaker, Geoffrey Edmund—Barnsley, Yorks.
(*University of Hull*)

Williamson, Graham Frank—Birmingham
(*University of Manchester*)

Yates, Charles Derrick—Wordsley, Worcs.
(*College of Advanced Technology, Birmingham*)

Four candidates took only the Mathematics papers this year and one satisfied the examiner. There were eleven candidates for the General paper, two of whom were taking this paper only and failed to satisfy the examiner ; two candidates were successful.

The candidates entered for Applied Heat withdrew before the examination but this paper is reproduced with the other question papers on pp. 242—262.

Table 1 shows the qualifications held by the 1960 candidates; the same information is given in Table 2 for all the candidates in the years 1952-60.

TABLE 1

Number of candidates and passes for the year 1960:—

	No. of candidates	*No. of passes*
Holders of degrees	64	27
Holders of the Higher National Certificate in Applied Physics ...	116	35
Others	8	1
	188	63

TABLE 2

Totals of candidates and passes for the years 1952-1960:—

	No. of candidates	*No. of passes*
Holders of degrees	210	82
Holders of the Higher National Certificate in Applied Physics ...	390	109
Others	54	8
	654	199

TABLE 3

1960 EXAMINATION

	No. of candidates	*No. of passes*
Physics I	124	36
Physics II	117	36
Physics III	22	1
Mathematics I	22	3
Mathematics II	22	3
More Advanced Physics	63	29
Applied Optics	2	0
Electronics	49	20
Mathematical Physics	5	1
Nuclear Instrumentation and Measurements	22	7
Spectroscopy	3	1
Statistics	6	2
X-rays	2	1
Practical Physics	15	4
General Paper	11	2

Papers set in the Graduateship Examination 1960

PHYSICS I—GENERAL PHYSICS AND ACOUSTICS

Examiner: PROFESSOR J. D. CRAGGS, M.SC., PH.D., F.INST.P.

MONDAY, 30th May—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. By describing the effect of forces acting normally outwards from all faces of a cube, show how the elastic constants of a solid are related. Give brief notes to indicate the methods of measuring three of the four constants involved.

2. Give the theory of a method for the measurement of the viscosity of a gas. Describe briefly the importance of results obtained in this way in relation to the kinetic theory of gases.

3. Describe experimental methods for the measurement of gas pressures from 10 mm of mercury to 10^{-11} mm of mercury.

4. Show how the surface tension of a liquid in the form of a large drop may be measured.

5. Define Young's modulus and show how this may be measured by the bent cantilever method.

6. Give an account of the physics of (i) the violin, and (ii) the organ.

7. Derive the Maxwell-Boltzmann formula for the distribution of molecular velocities of a gas. How could this distribution be investigated experimentally ?

8. Derive an expression for the velocity of propagation of longitudinal waves in a rod and give experimental methods for the verification of the result.

PHYSICS II—HEAT AND OPTICS

Examiner : J. R. ATKINSON, B.A., F.Inst.P.

MONDAY, 30th May—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Define the Kelvin scale of temperature and determine its relation to the scale defined by a perfect gas. Discuss briefly how absolute temperatures may be measured in practice.

2. Describe how liquid helium can be produced and give a brief account of its properties.

3. Discuss the methods by which an accurate estimate may be made of the amount of water vapour present in a given volume of air. Calculate the weight of 5 litres of air saturated with aqueous vapour at 18°C and 750 mm pressure. The saturation pressure of aqueous vapour at 18°C is 15·5 mm and the mass of a litre of dry air is 1·29 g at N.T.P.

4. Show that for any homogeneous substance

$$\left(\frac{\partial p}{\partial v}\right)_t \left(\frac{\partial v}{\partial t}\right)_p \left(\frac{\partial t}{\partial p}\right)_v = -1$$

where p, v, t denote its pressure, volume and temperature respectively.

The compressibility of paraffin oil is $62{\cdot}5 \times 10^{-6}$ per atmosphere. Its coefficient of cubical expansion is 9×10^{-4}/°C. If it is heated from 0°C to 30°C, what increase of pressure is necessary to keep its volume constant ?

5. Define what is meant by " black body radiation " and present a logical development of the evidence in support of the quantum theory based on studies of radiation emitted from hot bodies.

SECTION B

6. Give a critical account of modern methods by which the relative intensities of light sources of different colours may be compared.

7. Discuss the design parameters for a compound microscope and show how the magnification may be (*a*) calculated and (*b*) measured. Mention briefly some of the recent advances in the field of microscopy.

8. Define the conditions which are necessary and sufficient for interference phenomena to be observed from two light sources. In a conventional Young's fringe apparatus, a third slit is introduced ; determine the interference pattern produced on a screen, assuming that the centre slit is equidistant from the other two.

9. Give an account of the wave-surface in a uni-axial crystal, and show how it can be applied to find the direction of a ray refracted at the surface of the crystal.

The principal indices of refraction of Iceland spar are 1·658 and 1·486. The optic axis of the crystal is parallel to the surface, and a ray is incident in a plane at right angles to the optic axis making an angle of 45° with the normal. Calculate the direction of the refracted rays.

PHYSICS III—ELECTRICITY AND MAGNETISM

Examiner : PROFESSOR J. D. CRAGGS, M.SC., PH.D., F.INST.P.

THURSDAY, 2nd June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Give an account of the Townsend theory of spark breakdown of a gas.

2. Trace the historical development of our knowledge of isotopes with an account of the principal experimental techniques involved.

3. Describe techniques for the measurement of high voltages with a critical discussion of relative accuracies.

4. Write an essay on some of the recent work on the earth's magnetic field.

5. Describe, with appropriate analytical treatment, the bridge measurement of inductance at low frequencies.

6. Give the theory of the moving coil ballistic galvanometer for the measurement of a quantity of electricity and describe carefully the salient features of such an instrument. Briefly mention another method for making such measurements.

7. Explain precisely the action of electrostatic screens and describe applications of such devices.

8. Write an essay on the domain theory of magnetism.

MORE ADVANCED PHYSICS

Examiner : J. R. Atkinson, B.A., F.Inst.P.

TUESDAY, 31st May—9.30 a.m. to 12.30 p.m.

(*Answer* FOUR *questions*)

1. Give a critical description of the Michelson-Morley experiment. Explain the significance of the results obtained.

2. Compare and contrast the methods and results of X-ray and electron diffraction.

3. Discuss the various visual techniques used by physicists to investigate the properties and behaviour of charged particles.

4. Explain carefully the factors which control the current flowing in a diode valve. Derive an expression for the current in the case of a space-charge-limited diode with plane-parallel electrodes, stating clearly the assumptions made.

Show that in the above case the electric field at the anode is 4/3 of its value when no current is flowing.

5. Discuss the evidence in support of the band theory of solids and show how conductors, insulators and semi-conductors are thereby distinguished. How are p-type and n-type semi-conductors identified experimentally ?

6. Give an account of the nature of the information about molecular structure which is obtained by a study of (i) micro-wave, (ii) infra-red, and (iii) visible to ultra-violet spectra respectively.

7. " All atoms are of the same size and all atomic nuclei of the same density." To what extent is this statement true, and on what sort of information is it based ? Discuss those features of atomic and nuclear structure which are responsible for this difference between atoms and nuclei.

8. Discuss critically the contributions to physical knowledge that could be provided by a man-made earth satellite.

GENERAL PAPER

Examiner: N. Clarke, B.Sc., F.Inst.P.

TUESDAY, 31st May—9.30 a.m. to 12.30 p.m.

(*Answer any* FIVE *questions*)

1. If you were awarded a prize of £10 to be spent on any books other than scientific text-books, which books would you choose ? Why ?

2. Write a short history of an industry with which you are familiar.

3. Discuss the boycott of South African goods organized in March last.

4. Discuss Britain's export trade, mentioning in particular the main changes since 1938.

5. What is meant by (*a*) an oratorio, (*b*) a symphony, (*c*) a cantata, (*d*) a fugue and (*e*) a sonata. Quote examples.

6. If you could secure the passage of an Act of Parliament, without any of the usual restrictions on Private Members' Bills, what would be its main provisions ? Explain why you think this reform is needed.

7. Describe the main social welfare provisions in modern Britain.

8. Write short notes on any three of the following : General de Gaulle; Vice-President Nixon; Sir Anthony Eden; Mr. Nehru; Dr. Adenauer.

9. " There is no civilized, or even faintly civilized, nation which does not read, study, perform, salute (and actually enjoy) the works of William Shakespeare " (*Ivor Brown*). Why do you think this is so ? Which of Shakespeare's plays do you particularly like ? Why ?

APPLIED HEAT

Examiners :

A. E. De Barr, B.Sc., F.Inst.P., and

Professor M. W. Thring, M.A., F.Inst.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. A steam pipe, 4 in. outside diameter, is covered with two layers of insulating material, each 1 in. thick, the thermal conductivity of one material being three times that of the other. Assuming only the fundamental Fourier equation, show that the effective conductivity of the two layers is approximately 16% less when the better insulating material is on the inside than when it is on the outside.

Comment on the practical significance of this result.

If the better insulator has a thermal conductivity of 0·48 B.t.u./(sq. ft.) (hour) (°F per in.), and is placed next to the pipe, and the temperatures of the pipe wall and the outside of the outer layer of lagging are 450°F and 100°F respectively, what is the rate of heat loss per foot of pipe length ?

2. In a heat-exchanger a liquid is heated from T_1°C to T_2°C by means of steam condensing at T_3°C. Find, from first principles, the mean temperature difference between the liquid and the steam.

In a counter-flow heat exchanger of length L a liquid is cooled from 60°C to 40°C by means of cooling water heated from 20°C to 25°C. Assuming that the result obtained above can be applied to this heat exchanger, evaluate the mean temperature difference in the cooler.

If the inlet temperatures and the flow rates of the hot liquid and the cooling water remain unchanged, and the over-all heat transfer coefficient is constant, find the length of the cooler, in terms of L, needed to cool the hot liquid to 30°C, 25°C and 22·5°C respectively. Comment on the economic aspects of the result.

3. Show how Stefan's radiation law may be derived by thermodynamic reasoning.

Describe briefly a method of verifying the law experimentally.

In a tungsten filament lamp it may be assumed that all the energy supplied to the filament is lost by radiation and that the radiation received by the filament from its surroundings is negligible. If the diameter of the filament is 0·024 cm, its emissivity is 0·3 and the operating temperature is 2200°C, find the length of wire needed in a 100 watt lamp.

4. Discuss the physics of combustion and heat transfer from a steam-atomized oil flame in a steel melting open-hearth furnace.

5. Explain what is meant by infra-red heating, and discuss the advantages of this process for some industrial application.

For what purposes are dielectric heating and induction heating suitable ? What factors determine the electrical frequencies used for these forms of heating ?

6. Explain to what extent the CO_2 content of furnace flue gases may be taken as a guide to combustion efficiency.

The volumetric analysis of a boiler flue gas gave 11% CO_2, 1% CO and 7% O_2. The coal burnt had a calorific value of 13,500 B.t.u./lb. and its composition was 80·5% carbon, 4·5% hydrogen, 2·5% oxygen, the remainder being ash. Determine the air supplied per lb. of coal and the percentage heat loss because of incomplete combustion. (Assume that burning 1 lb. of carbon to CO gives 4,360 B.t.u. and to CO_2 gives 14,540 B.t.u., and that there is negligible carbon loss in the ash.)

What conditions might give rise to the above flue gas analysis ?

7. Explain why a steam turbine nozzle has to be convergent-divergent to obtain the highest possible velocity when the steam has a pressure of 100 lb./in.^{2} abs. and is expanding to 1 atmosphere.

8. Explain how electricity can be used to heat a room in such a way that the number of heat units supplied to the room is three times the amount of heat obtainable by consuming the electric power in a resistor.

9. Explain briefly the construction and physical principles underlying the use of instruments for measuring the temperature of an inaccessible radiant surface.

A total radiation pyrometer develops e.m.fs. of 0·5 and 2·5 mV when it is sighted on a black surface at temperatures of 1135°C and 1765°C respectively. What is the " scale-law " of the instrument.

The pyrometer is then sighted on a surface of emissivity 0·8 and an e.m.f. of 2·0 mV is recorded. What is the temperature of the surface ?

Numerical data

Stefan-Boltzmann constant, σ	$5{\cdot}72 \,.\, 10^{-12}$ watt cm^{-2} (°K)$^{-4}$
Mechanical equivalent of heat, J	$4{\cdot}18 \,.\, 10^{7}$ erg cal^{-1}

APPLIED OPTICS

Examiner : C. A. TAYLOR, D.SC., PH.D., F.INST.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(*Answer question 1 and* FOUR *other questions; question 1 must be attempted*)

1. A line object ½ inch long is perpendicular to the axis of a converging lens of focal length 3 inches and diameter 1 inch, and has one end on the axis at a point 1 inch to the left of the lens. A second converging lens of focal length 1 inch and diameter 2 inches is placed co-axially to the right of the first in such a position that all the rays from the object transmitted by the first lens just pass through the second.

Draw a full-scale diagram of the system distinguishing clearly between constructional and actual ray paths. Determine graphically the distance between the two lenses, and the position and size of the final image. Compare your result with that obtained by calculation. (Assume for the purpose of this question that the lenses are thin, and that the paraxial formulae apply.)

2. Discuss the Abbe theory of microscopic vision, and explain how it may be used as a basis for understanding (*a*) dark ground illumination, (*b*) phase contrast microscopy *and* (*c*) the limit of resolution for a microscope.

3. Discuss the limits of validity of the simple thin lens formulae in practical optical systems. Explain which of the limitations may be overcome by the use of aspheric surfaces. Outline the techniques used in creating and testing such surfaces.

4. Discuss the relationship between the energy and the luminosity associated with a beam of light. Explain how the relative sensitivity of the eye to different wavelengths differs for high and low levels of illumination.

Discuss the importance of the curve relating energy and luminosity in visual photometry, and explain how it might be obtained experimentally.

5. Describe carefully instruments for the accurate measurement of the refractive index of (*a*) a liquid (assume μ lies between 1·3 and 1·5) *and* (*b*) a gas.

6. Write an essay on " Astronomical Telescopes, Ancient and Modern."

7. Each of the following objects appears red to a normal observer, but in each case the origin of the colour is different:—(*a*) a red-hot poker, (*b*) a sheet of newly polished copper, (*c*) a neon discharge tube, (*d*) a red rose, (*e*) red ink, (*f*) the setting sun, (*g*) the red region of a rainbow. Explain carefully the physical reasons for the coloured appearance of each object, and discuss the differences that might be expected if the light from each were examined spectroscopically.

8. How would you produce a beam of circularly polarized light ? Assume that you have a light source, a pair of Nicol prisms, and access to sheets of optically uniform mica of all thicknesses, but no other optical apparatus. Describe carefully all the experiments that you would perform in order to produce a circularly polarized beam, and to demonstrate that it is circularly polarized.

9. A parallel beam of monochromatic radiation of wavelength 5890Å falls normally on to a plate in which are cut two identical narrow slits. The light then passes through a lens of 1 metre focal length, and the resulting diffraction pattern is received on a screen placed in its back focal plane.

The pattern consists of 5 more or less equally bright bands in the centre of the field, and then further bands on either side of very much weaker intensity. The centres of the bright bands are 0·4 mm apart. Calculate (*a*) the spacing of the two slits and (*b*) the approximate width of each slit. If a third identical slit were cut in the screen so that the three were equally spaced, how would the pattern change ?

ELECTRONICS

Examiner : A. E. De Barr, B.Sc., F.Inst.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(*Answer question 1 and* FOUR *other questions ; question 1 must be attempted*)

(*The required numerical data are given at the end of the paper*)

1. (i) Two valves are identical in all respects except for the material of their cathode surface. In one valve the work function of the cathode surface is 4·5 eV and in the other it is 1·5 eV. What will be the approximate ratio of their heater powers required for a given thermionic emission?

(ii) In a low-frequency amplifier the input voltage is applied across a 600 ohm resistor connected between the grid and cathode of a triode: the valve has an amplification factor of 20 and an anode slope resistance of 12,000 ohm. In the anode circuit is a 15 : 1 transformer feeding a resistive load of 60 ohm. Calculate the over-all gain in decibels.

(iii) A thyratron is to be employed as the discharging switch in a simple relaxation oscillator circuit in which a 0·01μF condenser is charged through a resistance of 50,000 ohm. If the supply voltage is 500 and the thyratron strikes at 260 volts and extinguishes at 10 volts, what will be the frequency of the oscillations ?

2. Discuss the physical principles governing the various ways in which electrons can be emitted from solids. Mention practical applications of each type of emission and comment on the properties of the emitting materials commonly used.

3. A germanium filament of thickness 1·5 mm is placed in a uniform magnetic field of flux density 0·2 Wb m^{-2} (2000 gauss). On passing a current of 1 mA through the specimen a Hall potential difference of 1·75 mV is observed. Deduce the number of current carriers per unit volume. Derive from first principles any formulae required.

Discuss the importance and the use that can be made of the results obtained from this type of experiment.

4. The anode current in a pentode valve may be written

$$I_a = f(V_a, V_{g_1}, V_{g_2}, V_{g_3})$$

where the symbols have their usual meanings. Starting with this assumption derive the approximate equation $i_a = g_m e_{gk}$ for small signals.

Summarize the advantages of pentode valves over triodes and draw the circuit of a typical pentode audio-amplifier stage, explaining the function and normal order of value of each component.

5. Discuss the frequency response of valve amplifiers.

A triode valve has a resistance R_K connected between its cathode and earth. The anode load is a resistance R. The input signal is applied between the grid and earth, whilst the output signal is taken off between the anode and earth. A by-pass condenser of capacity C is in parallel with the resistance R_K. Find the ratio of the voltage amplification at high frequencies to that for d.c. signals.

Mention a possible application for this type of circuit.

6. Compare the properties of a galvanometer and a thermionic valve for the measurement of small currents.

Describe and explain the equipment you would use with an ionization chamber in order (*a*) to measure a saturation current of 10^{-15} ampere, and (*b*) to count α-particles.

7. Describe, with reference to the physical principles involved, the operation of (*a*) a klystron oscillator, (*b*) a magnetron oscillator.

What factors determine (i) the upper and lower limits of frequency for which these oscillators are used and (ii) the output power obtainable from them ?

Mention some applications of klystron and magnetron oscillators.

8. Describe a modern form of linear time-base circuit, explaining carefully the reasons for the various components. Indicate how the speed of the time-base can be controlled, how synchronization can be effected, and how single-sweep operation can be obtained.

In a simple time-base circuit using a constant-current pentode the anode current of the pentode is approximately 20 mA and the capacity of the time-base condenser is $0{\cdot}01\mu$F. Calculate the speed of the time-base in cm.sec.$^{-1}$ given that the appropriate deflection sensitivity of the cathode-ray tube is 30 volts.cm^{-1}.

9. Describe, with the aid of suitable characteristics, the essential properties of a thyratron valve and explain why these differ from the properties of a high-vacuum triode. What factors determine the ionization and de-ionization times of a thyratron ?

Describe briefly some form of cold-cathode gas-filled valve and compare its properties with those of a thyratron.

Numerical data

Electronic charge, e	$1{\cdot}6 \ . \ 10^{-19}$ coulomb
Electronic mass, m	$9{\cdot}1 \ . \ 10^{-28}$ g
Boltzmann's constant, k	$1{\cdot}38 \ . \ 10^{-23}$ joule/deg. K

NUCLEAR INSTRUMENTATION AND MEASUREMENT

Examiners : A. E. De Barr, B.Sc., F.Inst.P., and
D. Greene, B.Sc., Ph.D., A.Inst.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions*)

(*The required numerical data are given at the end of the paper*)

1. Explain why stabilized power supplies are desirable for use with electronic equipment of the type used for detecting and measuring nuclear radiation.

Describe the operation of a simple series-parallel voltage stabilizer circuit and derive an expression relating the input and output voltages. How may the performance of the circuit be improved ?

2. Describe in detail the operation of practical versions of TWO of the following circuits : (i) a square-wave generator, (ii) an integrating circuit, (iii) a scale-of-two counter. Indicate typical values of each of the components and explain why these values are suitable.

3. Discuss in detail the growth of the activity of a radioactive material produced by the bombardment of a suitable target by a constant intensity beam of deuterons.

The reaction

$$C^{12} + H^{2} \rightarrow N^{13} + n$$

has a cross-section of about $3 . 10^{-22}$ cm^2 for 5 MeV deuterons. N^{13} is a positron emitter with a half-life of 9·9 minutes. Calculate the number of N^{13} nuclei present after a 15 minute exposure to a 100μA deuteron beam.

4. Describe and explain the use of a scintillation counter for the measurement of γ-ray spectra.

Discuss the factors affecting the choice of a suitable phosphor and photomultiplier for the scintillation counter.

5. Explain the operation of a complete counting equipment for use with a Geiger counter.

Discuss the possible errors involved in a count made with this equipment and explain how corrections can be made for some of these.

6. Write an account of the health hazards arising from the use of radioactive materials and discuss the precautions that should be taken to minimize them.

The dose-rate from a large cobalt source is 30 r.min^{-1} at 1 metre from the source. The $\frac{1}{10}$th value larger for Co^{60} radiation in concrete of specific gravity 2·2 is 12″. What is the thickness of concrete required to protect the occupants of an adjacent room, the nearest wall of which is 3 metres from the source ?

7. Describe the processes that occur when a β-particle expends its energy in a gas.

Explain how you would determine the maximum range of β-particles in a solid material and comment on some industrial applications of this process.

8. Define the Curie and describe a method of measuring accurately the absolute activity of a β-emitter.

The half-life of P^{32} is 14·3 days and it emits electrons the mean energy of which is 0·7 MeV. Calculate the activity in millicuries of 1 mg of P^{32}. If this is distributed uniformly throughout 10 g of tissue, calculate the dose-rate.

9. Describe and explain the operation of a modern form of mass spectrometer.

Describe the experimental procedure you would adopt in order to determine the relative abundance of the isotopes of carbon in a gaseous sample.

Numerical Data

Electronic charge, e	$1{\cdot}6 . 10^{-19}$ coulomb
1 rep	$\equiv 93$ erg g^{-1}

SPECTROSCOPY

Examiners:

A. E. De Barr, B.Sc., F.Inst.P., and

M. Milbourn, B.Sc., F.Inst.P.

TUESDAY, 31st May—2.00 to 5.00 p.m.

(*Answer questions 1 and 2 and* THREE *other questions : questions 1 and 2 must be attempted*)

1. Outline theoretical aspects of the excitation of radiations from atoms in various states, and discuss, in relation to this theory, the radiations arising from either an arc or a spark discharge.

A 50 c/s supply with a peak voltage of 10,000 V is used to energize a discharge. An inductor of 0·03 mH and a 0·005μF capacitor are included in the circuit. Sketch a suitable circuit diagram. What will be the electrical characteristics of the consequent discharge, and what types of radiation will originate from it ?

2. A transmission grating has 4500 lines in a total width of 4 cm and parallel light falls normally on it. Calculate (*a*) the angle at which the first order maximum for a wavelength of 5900Å would occur, (*b*) the angle at which the second order maximum for a wavelength of 6500Å would occur and (*c*) the resolving power for both first and second order spectra. Derive any formulae required.

What would be the effect on each of these calculations if the grating were masked so that only a width of 1 cm was allowed to transmit light, the other conditions being unchanged ?

3. Discuss the influence of flame temperature on the accuracy and sensitivity of flame photometric analysis. Include reference to the effects of other elements present.

What steps would you take to overcome the consequences of variations in flame temperature ?

4. Indicate the main optical components of any quartz spectrograph with which you are familiar, and discuss the factors that determine the position of the focal plane. Describe the adjustments that are necessary in order to maintain sharp focus. What experimental procedure would you adopt to set the instrument in optical adjustment ?

5. A photoelectric spectro-absorptiometer is to be used for the quantitative analysis of a mixture of two organic constituents. What sources of error, random or systematic, are likely to be encountered, and what steps should be taken to minimize them ?

6. Describe a method for establishing the relationship between relative intensity and optical density for a particular photographic emulsion. Include any relevant photographic theory.

Indicate the advantages and disadvantages of the method you choose.

7. Describe techniques for the production of replica gratings.

Indicate the types of instrument in which these are likely to be used, with particular reference to the optical systems concerned.

8. Discuss the industrial applications of infra-red spectrometry with particular reference to (*a*) the physical factors limiting the sensitivity and wavelength range, and (*b*) the type of information obtainable.

X-RAYS

Examiners:

A. E. De Barr, B.Sc., F.Inst.P., and
R. F. Farr, M.A., F.Inst.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(Answer FIVE *questions)*

(The required numerical data are given at the end of the paper)

1. Discuss, with reference to atomic structure, the effect of atomic number on the wavelength of the K emission spectrum of an element.

The $K\alpha_1$ line emitted from the iron ($Z = 26$) target of an X-ray tube falls on a crystal of face-centred cubic structure of lattice parameter 2·8Å. The first order "reflection" of the $K\alpha_1$ line from the (110) planes of the crystal occurs when the angle between the beam and the (110) planes is 30°. Estimate the value of the Rydberg constant, R.

2. An X-ray tube operates at 300 kVp. How could you determine the angle which the target makes with the axis of the tube?

If this angle is 71°, what area do you think would be covered for satisfactory radiography at a target film distance of 36 inches? Would you expect the area to remain constant throughout the life of the tube?

Under what circumstances would a target making an angle of 90° with the tube axis be used? In this case, what factors determine the area which may be satisfactorily covered at a given target-to-film distance?

3. Why is the use of high-tension rectification usually considered superior to self-rectification by an X-ray tube?

Describe circuits for half-wave and full-wave rectification suitable for use with an X-ray tube.

What would be observed at the control panel and in the radiographic results if one rectifier failed in each of these circuits?

Under what circumstances may a valve rectifier emit X-rays?

4. In what ways may (*a*) the quality and (*b*) the quantity of X- or gamma-radiation be described and defined? Explain clearly the physical phenomena involved in each case.

What is the intensity of 2·0 MeV radiation which delivers to air a dose-rate of 100 rad min^{-1}?

5. What is meant by (*a*) the exponential absorption of X-rays? (*b*) lead-equivalent?

Explain clearly the meaning and the trend of the figures in the following table :—

Thickness of material—inch	Lead equivalent (mm) for X-rays generated at			
	150 kV	200 kV	300 kV	400 kV
1	2·4	1·8	1·9	2·1
2	—	—	—	4·7
3	—	—	—	7·5
4	—	—	—	10·5

Discuss the application of (*a*) lead, (*b*) concrete, (*c*) barium sulphate, (*d*) zinc bromide in X- and gamma-ray protection.

6. A " film-badge " dosimeter incorporates a film one half of which is screened by a metal filter. After exposure to X-radiation of a given quality and processing under standard conditions, the optical density of the film is found to be proportional to the radiation dose. The relative sensitivity of the film is defined as the ratio of the dose of cobalt-60 radiation which produces a given optical density to the dose of radiation of another quality which produces the same blackening of the film. It is found to vary with the effective quantum energy of the radiation as follows:—

Effective energy (keV)	1250	200	90	80	70	60
Relative sensitivity						
Screened portion	1·0	1·0	1·0	1·3	1·7	2·4
Unscreened portion	1·0	1·5	6·0	13	25	70

Explain these figures in general terms and discuss the usefulness as a personal dosimeter of (*a*) the film alone, (*b*) the film and filter.

Show how the ratio of the densities of the screened and unscreened portions of the film can be used as an index of quality of radiation.

Such a badge worn by a radiation worker for one week recorded densities of 0·2 under the screen and 2·5 elsewhere. An identical film exposed to 1r of cobalt-60 radiation recorded a density of 1·2 all over the film. Estimate

(i) the dose received by the worker;

(ii) the quality of the radiation received.

Comment on the magnitude of the dose and mention how exposure to radiation of this quality might arise.

7. Give a comparative account of the main physical features of (*a*) a supervoltage X-ray equipment and (*b*) a kilocurie cobalt unit such as might be used for the radiography of thick steel sections.

A cobalt-60 source has an actual strength of 2,000 curies and an effective strength of 1,500 curies. Explain what is meant by this statement.

The source is housed in a protective container that allows significant radiation to escape only in a beam that covers a field of radius 50 cm at a distance of 100 cm. Estimate the rate at which energy is absorbed in the gamma-ray unit itself.

8. Give an account of the methods available for the radiographic examination of circumferential joint welds in pipes. Discuss the apparatus and technique employed, and the hazards possibly involved.

A gamma-ray source is displaced 6 inches from the centre of a thin-walled steel pipe, 3 feet in diameter. A band around the outside of the pipe, 12 inches wide on each side of the source, is covered with films. Estimate the density variation over the films, assuming correct exposure condition and a film gamma of 3·2.

9. Write an essay on the applications of X-ray diffraction.

Numerical data

Mass energy-absorption coefficient of air for 2·0 MeV radiation 0·0234 g^{-1} cm^2

Effective energy of gamma-radiation from cobalt-60 = 1·25 MeV

1 curie = $3{\cdot}7 \,.\, 10^{10}$ disintegrations/second

1 MeV = $1{\cdot}6 \,.\, 10^{-6}$ ergs

Velocity of electromagnetic waves in free space, $c = 3.\,10^{10}$ cm. sec^{-1}

MATHEMATICAL PHYSICS

Examiner : A. W. Gillies, B.Sc., Ph.D., F.Inst.P.

TUESDAY, 31st May—2.00 p.m. to 5.00 p.m.

(*Answer* FOUR *questions*)

1. The position of a physical system is defined by co-ordinates x and y. The kinetic energy T, and potential energy V are given by

$$T = \tfrac{1}{2}m(\dot{x}^2 + \dot{y}^2)$$

$$V = \tfrac{1}{2}m(a_1^2x^2 + 2hxy + a_2^2y^2)$$

Describe the general character of the motion of the system when disturbed from its equilibrium position, and show that the effect of the coupling term in the expression for the potential energy is to increase the separation of the natural frequencies.

2. Derive the differential equation for the transverse vibrations of a stretched string.

A string is stretched between two points a distance l apart. At $t = 0$ when the string is in its undisplaced position, the middle third is set in motion impulsively with velocity v. Determine the resulting motion, showing that all even harmonics will be absent.

3. For the plane irrotational motion of an incompressible fluid, define and discuss the use of the velocity potential φ and the stream function ψ, and show that they satisfy the equations

$$\frac{\partial\varphi}{\partial x} = \frac{\partial\psi}{\partial y}, \quad \frac{\partial\varphi}{\partial y} = -\frac{\partial\psi}{\partial x}$$

Show that the real and imaginary parts of the function $f(z) = \cosh z$, where $z = x + iy$, give possible values for a velocity potential and a stream function. Determine the equi-potential lines and the stream lines and discuss the fluid motion represented by this function.

4. Determine the equation for the radial flow of heat in the material between two concentric spherical isothermal surfaces.

The inner and outer surfaces of such a region are spheres of radii r_1 and r_2 maintained at constant temperatures V_1 and V_2 respectively. The conductivity of the material is a linear function of the temperature. Show that when steady flow is established, the heat transmitted through the material is the same as if it had constant conductivity equal to its actual value at the temperature $\tfrac{1}{2}(V_1 + V_2)$.

5. Describe briefly the use of electrical images in the solution of electrostatic problems.

An insulated conducting sphere of radius a carries a charge Q. A point charge Q' is placed at a distance $b(>a)$ from the centre of the sphere. Show that the surface density at the point of the sphere most remote from Q' will be reduced to zero if

$$Q' = -\frac{Qb(a+b)^2}{a^2(a+3b)}$$

What is then the surface density at the point of the sphere nearest to Q' ?

6. U and V are scalar point functions within a region $\mathscr{R}$ bounded by a closed surface $\mathscr{S}$. By applying Gauss' divergence theorem to the vector function U grad V deduce Green's theorem.

If V satisfies Laplace's equation in the region $\mathscr{R}$ show that

$$\iint_{\mathscr{S}} V\frac{\partial V}{\partial n}\,dS = \iiint_{\mathscr{R}} (\text{grad } V)^2\,dv$$

dS and dv being surface and volume elements of $\mathscr{S}$ and $\mathscr{A}$ respectively, and $\partial V/\partial n$ being the derivative of V normal to $\mathscr{S}$.

What deductions can be drawn from this relation if it is known that on $\mathscr{S}$, either V is constant, or $\partial V/\partial n$ is zero?

7. Write down Maxwell's equations for an isotropic dielectric and show that both **H** and **E** satisfy an equation of the form

$$\nabla^2 \mathbf{F} = \mu g \frac{\partial \mathbf{F}}{\partial t} + \mu \varepsilon \frac{\partial^2 \mathbf{F}}{\partial t^2}$$

where **F** represents either **H** or **E**, and μ, ε, g are the permeability, dielectric constant, and conductivity respectively.

Obtain a solution in which **H** is of the form $(0, H_0 e^{i(\omega t - \beta x)}, 0)$. Show that β will be complex if $g \neq 0$ and ω is real. Explain the significance of this and describe the general character of the solution.

8. The Schrödinger equation of a linear harmonic oscillator is

$$\left\{ \frac{d^2}{dq^2} + \frac{8\pi^2 m}{h^2}\left(E - \tfrac{1}{2} f q^2\right) \right\} \psi = 0.$$

Show that one solution is $\psi = a_0 e^{-\frac{1}{2}\alpha q^2}$ when $E = h^2 \alpha / (8\pi^2 m)$,

where $\alpha = 2\pi m \omega_0 / h$ and $\omega^2 = f/m$.

By substituting $\psi = e^{-\frac{1}{2}\alpha q^2} v$ obtain

$$\frac{d^2 v}{dq^2} - 2\alpha q \frac{dv}{dq} + (\lambda - \alpha) v = 0$$

where $\lambda = 8\pi^2 m E / h^2$ is proportional to the total energy E of the oscillator. Show that this equation has polynomial solutions for certain values of λ and infer the permissible energy levels of the harmonic oscillator.

9. Observer O' is moving relatively to observer O with velocity v in the direction of their common x axis. They both observe a train of plane light waves. Derive the relations.

$$\nu = \beta \nu' \left(1 - v \cos \theta' / c\right)$$

$$\cos \theta = \frac{\cos \theta' - v/c}{1 - v \cos \theta' / c}$$

$$\sin \theta = \frac{\sin \theta'}{\beta \left(1 - v \cos \theta' / c\right)}$$

connecting the frequencies and directions of incidence of the waves as observed by the two observers.

STATISTICS

Examiner : E. D. VAN REST, M.A., B.SC., F.INST.P.

TUESDAY, 31st May—2.00 to 5.00 p.m.

(*Answer not more than* FOUR *questions. These should include at least ONE from the first three*)

1. A resistance coil used as a sub-standard is measured at two laboratories at the beginning and end of a lengthy piece of co-operative work. The recorded deviations in convenient units are as follows:

1st Lab.	1st occasion	44,	105,	− 8,	98,	123
	2nd occasion	143,	133,	155,	154,	218
2nd Lab.	1st occasion	148,	144,	3,	61,	65
	2nd occasion	147,	166,	91,	170,	76

Is there any evidence (*a*) of a change over the period of the value of the resistance ? (*b*) of bias with respect to one another of the two laboratories ?

State your reasoning, give your calculations and mention any assumptions used to arrive at your answer.

2. From an experiment to test the unbiassed nature of an analytical procedure the following results were obtained on a number of samples containing known amounts (known exactly by admixture) of the impurity :—

mgs impurity found	5·74	6·72	7·77	8·73	9·72	11·68	15·62	17·61	19·60	21·67
mgs impurity present	6·00	7·00	8·00	9·00	10·00	12·00	16·00	18·00	20·00	22·00

Make any calculations and tests you think appropriate to enable you to discuss the nature of the bias which is apparent. What advantage has a test based on the ideas of regression over a simple significance test of the differences ?

3. The following numbers of faults were observed in 100 consecutive 4-yard lengths of cloth:—

No. of faults, r	0	1	2	3	4	5	6	7
No. of lengths with r faults	10	27	26	19	12	4	1	1

Test whether these observations are consistent with an equal chance of a fault occurring in each increment of the length. If they are, estimate the length l such that in the long run only 10% of the intervals between faults in the original uncut material will exceed l.

4. Define the two quantities F and χ^2 sometimes used in statistical tests and explain from your definitions why the entries in the χ^2 table for a given P and number of degrees of freedom n, are n times those in the F table for the same P and (n, ∞) degrees of freedom.

Wafers of silicon are etched in order to reduce their thickness to a standard value. The following observations of thickness were made on two samples of six wafers taken after 90 seconds and 140 seconds etching. The variance of the unetched wafers is known to be $\sigma^2 = 1{\cdot}1\ (10^{-3}\ \text{inch})^2$.

Thickness at $t =$ 90 secs.	14·91	13·34	15·23	16·54	13·52	13·38	10^{-3} inch
at $t = 140$ secs.	7·58	11·30	11·12	8·35	6·95	8·85	10^{-3} inch

Is there evidence of increase in variability with time of etching ?

5. If x and y_i $(i = 1, 2, 3 \ldots n)$ are deviations from their mean values of two variables with sample standard deviations s_x and s_y respectively, show that

$$1 - \frac{1}{2n}\sum_{i=1}^{n}\left(\frac{x_i}{s_x} - \frac{y_i}{s_y}\right)^2 = r$$

where r is the sample estimate of the correlation coefficient.

6. If errors of $1\frac{1}{2}$% are made in the measurement of the sides of a rectangle, what would be the maximum error met with in determining the area ?

If the coefficient of variation of a measurement of length is $1\frac{1}{2}$% what is the coefficient of variation of the determination of the area obtained as the product of two such lengths and what is the magnitude of the error unlikely to be exceeded ?

Explain in detail the differences between these two questions which require the answers to be different and contrast the meanings of the answers.

7. Write briefly about ONE of the following:—

(*a*) The advantages and drawbacks of acceptance sampling schemes. Explain the terms: process average, average outgoing quality limit.

(*b*) The use of the randomized block (or other) design to facilitate the analysis and interpretation of an experiment.

(*c*) The use of range as a measure of variation.

8. During a production process the numbers of good and defective items produced were recorded on a number of successive days as:—

Number good	3678	3500	3124	3888	3246	3274	3480
Number defective	70	68	60	74	61	65	70

Using the deviations of the daily figures from the average over the period, test whether the process may be regarded as stable as regards fraction defective.

MATHEMATICS I

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

WEDNESDAY, 1st June—9.30 a.m. to 12.30 p.m.

(*Answer* SIX *questions*)

1. Show that the equation $2x^3-3x^2-12x+21=0$ has only one real root, and determine this root correct to three decimal places.

2. (i) $f(x)$ and $g(x)$ are polynomials of degree n, neither of which vanishes for $x=a$. Show that

$$\frac{f(x)}{(x-a)\,g(x)}=\frac{A}{x-a}+\frac{f_1(x)}{g(x)}$$

where $f_1(x)$ is a polynomial of degree less than n, and $A=f(a)/g(a)$

(ii) Show that $\displaystyle\int_0^1\frac{(x^2+4)\,dx}{(x-4)\,(x^2-4)}=2\log 3-8/3\log 2.$

3. By using the substitution $v=u/r$, or otherwise, obtain the general solution of the differential equation

$$\frac{d^2v}{dr^2}+\frac{2}{r}\frac{dv}{dr}+k^2v=0$$

What is the particular solution for which

$$v = 1 \text{ when } r = 0\ ?$$

4. If $F(r,\theta) = f(r)\sin^2\theta$ satisfies the equation

$$r^2\frac{\partial^2 F(r,\theta)}{\partial r^2} + \sin\theta\frac{\partial}{\partial\theta}\left(\frac{1}{\sin\theta}\frac{\partial F(r,\theta)}{\partial\theta}\right) = 0$$

show that $f(r)$ must satisfy

$$r^2\frac{d^2f(r)}{dr^2} - 2f(r) = 0$$

Obtain a solution of the equation for F such that $F = O$ when $r = a$ for all values of θ, and $F = 1$ at the point $r = 2a$, $\theta = \pi/2$.

5. An ellipsoid has the equation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

with $a > b > c$. If $P(x', y', z')$ is a point on this ellipsoid show that the tangent plane at P has the equation

$$\frac{xx'}{a^2} + \frac{yy'}{b^2} + \frac{zz'}{c^2} = 1$$

If this tangent plane also touches the sphere with centre at O and radius b, show that

$$\frac{x'^2}{a^4} + \frac{y'^2}{b^4} + \frac{z'^2}{c^4} = \frac{1}{b^2}.$$

6. $\mathbf{a}$ and $\mathbf{b}$ are two given vectors and an unknown vector $\mathbf{v}$ has to satisfy $\mathbf{b} + \mathbf{a} \times \mathbf{v} = k\mathbf{a}$ where k is a suitable scalar factor. Either by interpreting the equation geometrically, or by using the identity $\mathbf{p} \times (\mathbf{q} \times \mathbf{r}) = (\mathbf{p}.\mathbf{r})\,\mathbf{q} - (\mathbf{p}.\mathbf{q})\,\mathbf{r}$ show that

$$v = \frac{\mathbf{a} \times \mathbf{b}}{\mathbf{a}^2} + \lambda\mathbf{a}$$

where λ is an arbitrary scalar factor, and determine the value of k.

7. (i) Explain how values are defined for $\cos z$ and $\sin z$ when z is a complex number.
   (ii) Determine the real and imaginary parts of $\cos(\pi/3 + i\log 2)$
   (iii) Show that

$$|\cos(x + iy)|^2 = \tfrac{1}{2}(\cosh 2y + \cos 2x)$$

and deduce that the only values of z for which $\cos z = 0$ are the real values $\pm\pi/2$, $\pm 3\pi/2, \ldots$

8. A particle of mass m is projected vertically upwards in a medium in which the resistance is kv^2 when the speed is v. If the initial speed of projection is $(mg/k)^{\frac{1}{2}}$ show that when the particle returns to the starting point it will have lost half the kinetic energy with which it started.

9. A particle P moves under the action of a force of attraction of magnitude $F(u)$, towards a fixed centre O, where $u = 1/OP$. Derive the equation

$$\frac{d^2u}{d\theta^2} + u = \frac{mF(u)}{h^2u^2}$$

and show that when $F(u) = ku^2$, the hodograph of the motion is a circle, i.e. if the velocity vector $\overrightarrow{O_1V}$ is drawn from a fixed origin O_1, the locus of V is a circle.

10. Two equal uniform rods AB, BC each of weight W and length $2a$, are freely jointed at B. The rods form an angle θ in a vertical plane, with the ends A and C resting on a smooth horizontal table. If the system is held in equilibrium with θ equal to a right angle, by a string joining A to the midpoint of BC, show by the method of virtual work, or otherwise, that the tension in the string is $\sqrt{5}W/(2\sqrt{2})$.

MATHEMATICS II

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

WEDNESDAY, 1st June—2.00 p.m. to 5.00 p.m.

(*Answer* SIX *questions*)

1. (i) Find the most general solution of the simultaneous equations

$$\begin{aligned} x + y - z &= 5 \\ 2x + 4y - 5z &= 20 \\ 5x + y + z &= 5 \end{aligned}$$

(ii) Find the values of λ for which the following equations have a solution other than $x = y = z = 0$

$$\begin{aligned} 2x - 3y + z &= \lambda x \\ 3x + y + 3z &= \lambda y \\ -5x + 2y - 4z &= \lambda z \end{aligned}$$

2. A solid has the form of the hemisphere $x^2 + y^2 + z^2 < a^2$, $z > 0$. The density ρ at any point (x, y, z) within this hemisphere is given by

$$\rho = \rho_0 \left(1 + \frac{x^2}{a^2} + \frac{y^2}{a^2}\right)$$

where ρ_0 is a constant. Show that the mass of the body is $\frac{14}{15}\pi a^3 \rho_0$ and determine the position of its centre of mass.

3. If $y = \int_0^x f(x, \xi)\, d\xi$ show that

$$\frac{dy}{dx} = f(x, x) + \int_0^x \frac{\partial f(x, \xi)}{\partial x}\, d\xi.$$

Hence show that

$$y = \int_0^x f(\xi)\, \frac{\sin k(x - \xi)}{k}\, d\xi$$

satisfies the differential equation

$$\frac{d^2y}{dx^2} + k^2y = f(x)$$

with the initial conditions $y = \frac{dy}{dx} = 0$ at $x = 0$

4. If z is a function of the two variables x, y which satisfies the equation

$$x\frac{\partial z}{\partial x} + y\frac{\partial z}{\partial y} = nz$$

prove that

$$x^2\frac{\partial^2 z}{\partial x^2} + 2xy\frac{\partial^2 z}{\partial x\partial y} + y^2\frac{\partial^2 z}{\partial y^2} = n(n-1)z$$

5. An electrical device produces a potential pulse in a certain circuit, the potential v assuming large values during a short interval between times $t = -\frac{1}{2}\tau$ and $t = +\frac{1}{2}\tau$. This pulse is repeated at regular intervals so that v is a periodic function of t of period T. Assuming the pulse to be symmetrical about its mid-time, and that v is zero between pulses, show that if $\tau \ll T$ the amplitudes of the lower harmonics in the Fourier expansion of v are equal and independent of the precise shape of the pulse. Estimate roughly the order of harmonic for which this ceases to be true.

6. A function x of the independent variable t satisfies the differential equation

$$\frac{d^2x}{dt^2} + 2\frac{dx}{dt} + x = 2\cos t$$

with the initial condition $x = 0, \frac{dx}{dt} = 0$ at $t = 0$. Find x as a function of t, sketch the graph of x against t for $t > 0$, and show that the first maximum of x for $t > 0$ occurs after $t = \frac{\pi}{2}$.

7. The probability of success in a trial of a particular event is p and of failure q. Prove that the probability of r successes in n independent trials is the coefficient of t^r in the expansion of $(q+pt)^n$.

Determine the mean and the variance of this frequency distribution.

8. **r** is the position vector of a variable point P and **a**, **b** are constant vectors. Show that if

$$\mathbf{r} = \mathbf{a} + \lambda\mathbf{b}$$

P will describe a certain straight line as the scalar factor λ varies.

If a second straight line is given by

$$\mathbf{r} = \mathbf{a}' + \mu\mathbf{b}'$$

show that the lines will intersect if the scalar triple product $[\mathbf{b}, \mathbf{b}', \mathbf{a}-\mathbf{a}'] = 0$ and find an expression for the shortest distance between them if they do not intersect.

9. A conical shell of uniform thickness has base radius r and height h satisfying the relation $r^2 = 2h^2$. Find its radii of gyration about its axis and about a perpendicular line through its vertex. Deduce the radius of gyration about a generator.

10. The position at time t of a frictionless mechanical system with one degree of freedom is determined by the co-ordinate x. The kinetic energy of the system is $\frac{1}{2}M(dx/dt)^2$ where M is constant, and its potential energy is a function of x which decreases as x increases from an asymptotic value V_1 as $x \to -\infty$ to V_2 at $x = 0$ and further to a minimum value V_0 at $x = 1$, after which it increases, approaching V_2 as $x \to \infty$.

Describe the motion of the system if released from rest at a position where x is (i) negative, (ii) zero and (iii) positive.

If near $x = 1$ the graph of x against t, approximates to $V = V_0 + U(x-1)^2$ find the period of small oscillations about the equilibrium position in terms of M and U.

PRACTICAL PHYSICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P., and
J. Yarwood, M.Sc., F.Inst.P.

FRIDAY, 27th May

(All day, beginning at 9.30 a.m.)

(Six hours allowed)

(TWO *questions, selected by the Examiners, will be allotted to each candidate*)

1. A wooden lath is clamped at one end so that it extends horizontally. Determine by means of an optical level the radius of curvature of the lath at three distances from the clamped end when the free end is loaded. Hence, find Young's modulus for the wood.

2. Construct a simple valve voltmeter and obtain for it a calibration curve for alternating 50 c/s e.m.f. inputs over the range from 0 to 6 volt r.m.s.

3. Find the temperature of a Bunsen flame by means of the apparatus provided.

4. Determine how the mutual inductance of the two coaxial flat coils varies with their separation.

5. Use the diffraction grating to find the mean wavelength of the light transmitted by a given optical filter.

6. Determine the characteristic of the Geiger-Müller counter tube. Record the Geiger threshold voltage and the slope of the plateau in counts per minute per volt.

7. For water, the variation of the coefficient of viscosity η with temperature T is given by the equation :

$$\eta = A \exp (c/T)$$

where A and c are constants.

With the apparatus provided find values for c and A.

8. Find the current and charge sensitivity of the ballistic moving-coil galvanometer.

9. Determine by means of a photoelectric cell the variation of the illuminating power of the lamp with the electric power consumed.

The Journals

PRINCIPAL CONTENTS OF THE SEPTEMBER, 1960, ISSUES

British Journal of Applied Physics: Volume 11, No. 9

Summarized proceedings of a conference on X-ray analysis, London, November, 1959. By A. L. Mackay and G. J. Bullen.

The Autumn Conference of the X-ray Analysis Group of The Institute of Physics was held at The Institution of Civil Engineers, London, on November 13 and 14, 1959. The topics under discussion were "Structure analysis" and "Apparatus and experimental techniques".

Pumping characteristics of a titanium droplet getter-ion pump. By L. Holland, F.Inst.P., and L. Laurenson.

The performance has been studied of a 12in. diameter titanium getter-ion pump with an evaporated-getter area of 3400 cm^2. The titanium was evaporated from an electron-bombarded molten bead suspended *via* a frozen zone from a cooled anode ; a triode electrode system was used for ionization pumping. The sorption rates of a number of gases were measured in the pressure range 10^{-4}–10^{-8} mm of mercury. The pumping speed for nitrogen was enhanced by operating the ionization source during evaporation. The h.t. voltage used with the vapour source influenced the form of the titanium bead, and at low voltages (approximately 800 V) and high power inputs (approximately 465 W) large metal droplets were obtained giving the highest evaporation and sorption rates. Sorption rates were greatly increased if a diffusion pump was in operation during gettering, because impurity gases slowly sorbed by the getter-ion pump were more effectively removed. Pumping speeds in l./s at 10^{-6} mm of mercury for the getter-ion pump with a diffusion pump (10 l./s) in operation and a titanium evaporation rate of 40 mg/min were as follows: oxygen$_2$—2450; nitrogen$_2$—4500; hydrogen$_2$—1600; air—600; argon—2·5; Calor gas—90. The low pumping speed of air was due to the low sorption rate of the argon component. Hydrocarbon gases were slowly sorbed and when mixed with active gases greatly reduced their pumping speed. The pump-down characteristics of the getter-ion pump were examined and it was found that the ultimate pressure was only slowly regained after exhausting oxygen. The sorption efficiency can be found from the equation : $S_m = \alpha S_0$, where S_m is the measured sorption rate per unit getter area (l./s cm^2), S_0 is the ideal sorption rate and α the sorption coefficient. Values of α measured at 10^{-6} mm of mercury were as follows : oxygen$_2$—0·068 ; nitrogen$_2$—0·12; hydrogen$_2$—0·012 ; possible reasons for the low value of α for hydrogen are considered.

Numerical investigation of a range of unipotential electron lenses. By J. Vine.

An electronic digital computer has been applied to the computation of focal lengths and spherical aberration constants of unipotential lenses, utilizing field data obtained from a resistance network analogue. Results obtained are presented in graphical form and shown to be in good agreement with published experimental results, but not, in the case of spherical aberration constants, with results based on analytical approximation to the axial potential distributions. The sources of error in the computations are discussed, and the accuracy of the results estimated.

Emission of negative ions of oxygen during the activation of oxide-coated cathodes. By N. A. Surplice, A.Inst.P.

Oxide-coated cathodes have been used as ion sources in a simple mass spectrometer and have been found to emit atomic negative ions of oxygen during their activation at high temperatures (1150–1275°K). A retarding potential at the collector was used to separate the ions emitted by the cathode from the ions formed in the residual gas. Most of the oxygen ions from the cathode arrived at the collector with more energy than they could have obtained from the potential difference across the electron gun, and their number increased as the cathode became more active. The evidence suggests that the ions were formed by dissociation of the oxide coating, then diffused to the surface and were removed by positive ion bombardment. Such a process would leave oxygen vacancies in the oxide which would act as electron donors and increase its electron emission.

Sorption and desorption of gas in a hot-cathode ionization gauge. By F. A. Baker, Grad.Inst.P., and T. A. Giorgi, Grad.Inst.P.

An omegatron has been used to analyse continuously the gases present during sorption/desorption experiments with a hot-cathode ionization gauge. It is shown that the most abundant residual gas at the termination of ion sorption pumping is carbon monoxide.

Ten per cent or less of the total gas originally sorbed is readily recovered at an exponential rate, indicating that this fraction of the gas is held at solid surfaces rather than within the solids themselves. It is also found that the fraction of gas that is readily recovered diminishes with successive pumping and recovery according to the relation $(i_+)^2{}_{max} \propto 1/t$, where t is the time recorded from initial operation of the experimental gauge and $(\mathrm{i}_+)_{max}$ is the positive ion current corresponding to the maximum pressure attained during recovery.

Solution of ladder networks containing non-linear resistances. By T. Kovattana and J. R. Barker, F.Inst.P.

A graphical method of solving network problems involving non-linear and/or negative resistances is described and fully developed for the case of ladder networks. Such networks have been used for the solution of non-linear differential equations, using an analogy based on finite differences, and the examples given in this paper are of this application.

Passage of current through the glass envelope of a receiving-type valve. By H. N. Daglish, A.Inst.P.

In normal operation of receiving-type valves, with soda glass envelopes, a small current may flow through the glass to an external coating. Part of this current consists of positive ions generated by the flow of electrons through the atmosphere inside the envelope. As the pressure inside the valve falls during operation, the value of the ratio of the current through the envelope to the anode current flowing in the valve also falls, eventually reaching a stable value which is independent of pressure. This residual value is due to the emission of photoelectrons from the inside of the glass, when bombarded by X-rays generated at the anode. It therefore depends upon the nature of the anode surface and upon the anode potential. The continuous passage of this photoelectric current through the glass may generate small quantities of gas by electrolysis, and so affect the behaviour of the valve. Experimental evidence suggests that the risk of permanent damage to the cathode emission is very small.

Temperatures reached in a bimetallic brake drum. By T. P. Newcomb, A.Inst.P.

A solution is given to permit the determination of the temperature attained at the friction surface of a bimetallic brake drum during a single brake application. No assumptions are made concerning the manner in which heat is shared between the drum and lining. This solution is then compared with those obtained when all the heat generated is assumed to enter the drum, and when the amount of heat entering the drum is dependent on the thermal properties of the cast iron and brake lining material only.

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Error of rectifier-type milliammeters in low-resistance circuits. By J. Wilbur-Ham and W. E. K. Gibbs.

Although a bridge-rectifier meter indicates r.m.s. current when the current is sinusoidal, a sinusoidal voltage produces a non-sinusoidal current, and hence an error in the indication, because the resistance of a copper-oxide rectifier is non-linear, varying as the − 0·7 power of the current. Series resistance tends to swamp the non-linearity, and the error, calculated by arithmetical integration, is shown on a nomogram relating error, series resistance and meter indication. Experiment confirms the results.

Daylight factor meter. By D. P. Turner.

A brief survey and criticism of existing methods of measuring daylight factors is followed by a description of an improved daylight factor meter, in which the current outputs of two photoelectric cells are compared by a null-balance method. When one cell is exposed inside the building and the other outside, the ratio of the illuminations at the two positions is indicated directly on a calibrated scale by the balance position of the potentiometer. The circuit is so arranged that the load resistances of the cells are unchanged by changes in the balance position and, for a constant daylight factor, the balance position is not affected by changes in the average luminance of the sky. The instrument can be calibrated directly on an optical bench, either for use with the outside cell exposed to a full hemisphere of sky or for use with the outside cell so masked that light is only received from a part of the sky.

Time-sorter for use in the nanosecond range. By G. Jones.

The paper presents the design of a time-to-amplitude conversion circuit employing delayed fast coincidence techniques for use in the nonosecond region. This circuit has a linear time calibration over the range 1 to 10 ns, a resolution time of less than 0·05 ns and a variation of time calibration less than 0·03 ns per day is achieved. A resolution time of 0·8 ns was found when detecting coincidence between γ-rays from a ^{60}Co source.

Isotopic analysis of boron in boron trifluoride by mass spectrometry, and measurement of natural boron 10 concentration. By P. G. Bentley.

A conventional mass spectrometer is used for precise measurements of the isotope ratios of boron in boron trifluoride samples with widely differing concentrations of boron 10. "Memory" effects caused by the adsorption of boron trifluoride on to the surfaces of the inlet system have been investigated, and it is found that these can be reduced to a workable level by careful design of the inlet system. By blending together enriched and depleted boron trifluoride, standard samples with known isotopic constitutions are prepared and used to calibrate the mass spectrometer. The true and measured isotope ratios are thus found to differ by several per cent, an effect attributed to mass discriminations in the ion source. After correcting for this error, the boron 10 atomic concentration in some naturally-occurring boron is found to be 19·27 ±0·13%.

Ratiometer for low-current mass spectrometry. By F. D. S. Butement and N. P. Finkelstein.

A new technique for the measurement of isotopic abundance ratios has been developed. Individual ions in the beam are detected, and an automatic switching device counts the total number of ions in each of the two mass beams being compared. The system is simple to operate and has been found to give very accurate results. No elaborate stabilization of ion-source emission or other operating conditions is necessary.

Measurement of space density of charge in flowing liquids. By A. Schuringa and C. Luttik.

A description is given of an instrument for the detection and measurement of the space density of charge in electrically charged flowing liquids, such as white petroleum products. It is based on the measurement of the dielectric displacement at a metal rod placed in the axis of a pipe carrying the liquid under test. The advantage over existent measuring methods is that no pipe-line section or other part of the installation need be insulated.

Reduction of dead-time in halogen-quenched Geiger counters. By B. B. Trott.

A new type of charge-reduction has been found with a halogen-quenched X-ray Geiger counter. A practical circuit has been developed which reduces the effective dead-time of the counter by a factor of ten. The dead-times were measured by a new method.

Apparatus for the measurement of gas velocity in furnaces and models. By A. E. Pengelly, A.Inst.P.

A range of pitot tubes is described together with an electromagnetic transducer micromanometer. The assembly is designed for the measurement of gas velocity over a large range of temperature, and pollution with velocities as low as 40 cm/s. Some applications are described.

Simple continuous chart and integrating device for a Joyce-Loebl microdensitometer Mk. I. By G. Farrow and D. Preston.

Two simple devices are described which may be added to a Joyce-Loebl microdensitometer. The continuous chart device enables a chosen expansion ratio of any film being scanned by the microdensitometer to be recorded on one piece of chart paper. The existing mechanical link between the original chart table and film carriage table has been preserved. The integrating attachment allows the area beneath the recorded trace to be determined while the trace is being produced.

Measurement of thermal diffusivity of semiconductors by Ångström's method. By A. Green and L. E. J. Cowles.

An apparatus for the accurate determination of the thermal diffusivity of semiconductors, which utilizes the thermoelectric properties of such materials, is described. In its present form, the apparatus can be used between room temperature and 180°C. The application of the method is illustrated by an experiment using a single-crystal specimen of bismuth telluride.

Heavy-water electrolysis unit for generation of deuterium gas provided with automatic switch-off and safety devices. By P. K. Dutt.

An electrolysis apparatus has been constructed for the safe and trouble-free generation of deuterium gas from heavy water for experimental purposes. It has been found particularly suitable for introducing the gas at a rate of millilitres per minute (S.T.P.) into a vacuum system without the use of an extra pumping unit, because the electrolysis is done under atmospheric pressure and not in a vacuum. The apparatus is equipped with electrical control-relays and needs little attention. It operates within a specified pressure range of the liberated deuterium gas, and is automatically shut off if the pressure exceeds a certain value. There is an almost complete absence of danger of explosion arising from the electrical devices should the generated deuterium gas be accidentally mixed with air.

Temperature-controlled permanent magnet for high-resolution nuclear magnetic resonance. By B. A. Evans and R. E. Richards.

The design and construction of a large temperature-controlled permanent magnet is described and the considerations given towards obtaining a high degree of field uniformity. Using current shims and a spinning sample, a resolving power and stability of a few parts in 10^8 may be obtained at any time and, with care, 1 part in 10^8 can be achieved.

Improved design for an auto-focus range-finder. By H. Asher, L. Dodin, and H. P. Mulholland.

Various designs for a camera range-finder with parallel mirrors and a variable prism-unit have been described. In each design certain parts of the range-finder shared the motion of the camera lens in focusing. Here a further design of this type is described in which there is no relative movement of the mirrors.

Papers accepted for publication in *Proceedings of The Physical Society*

Rotational-Translational Relaxation Time in H_2 calculated from Thermal Conductivity. By B. N. Srivastava and A. K. Barúa.

An approximate method has been developed for obtaining the value of ζ, the number of collisions required to make a rotational-translational energy transfer in a diatomic gas from the thermal conductivity data and the geometry of the apparatus employed in the conductivity measurements. The values of ζ for H_2 calculated at different temperatures are in fair agreement with the values obtained by other methods. They also show that ζ increases with rise of temperature.

Four Nucleon Reactions with Central Forces. By P. G. Burke and W. Laskar.

The four nucleon reaction has been formulated using the resonating group method and including the three groupings DD, nHe^3, and pT. The central potential used is of gaussian shape with exchange dependence (Serber and Symmetrical exchange have been mainly investigated).

The wave functions for the nuclear ground states are double gaussian for Deuteron and single gaussian for T and He^3, the parameter being determined by variational methods to fit the binding energies.

Coupled integro-differential equations have been derived for each value of the total spin and angular momentum of the corresponding system.

Preliminary results have been obtained by including only one channel for DD and are given here.

The Hamiltonian formalism of damping in a tuned circuit. By P. G. Burke and W. Laskar.

The idea behind this work is the supposition that it should be possible to introduce damping into the quantum mechanical discussion of a harmonic oscillator without a detailed description of the damping mechanism. A study is therefore made of an L,C circuit coupled to an artificial (or transmission) line, using a Hamiltonian formalism. The whole system is conservative but, for the transmission line case, the L,C circuit behaves as if it is damped. The most probable form for the Hamiltonian does not exhibit the damping in an obvious way. It is shown that by a suitable change of variables the Hamiltonian can be split into two time-dependent commuting parts, one of which has the form

$$e^{-2\alpha t}\frac{\breve{P}^2}{2C} + e^{2\alpha t}\frac{\breve{Q}^2}{2L}$$

which has been previously used in a study of 2-level masers, and which does display the damping. The new operators, $\breve{Q}$ and $\breve{P}$ are studied and it is shown that they are related to the charges and currents in the L,C circuit, but with the noise components due to the resistive loss (the transmission line) omitted. They are thus perhaps more natural variables to use than the actual charges and currents which do contain noise components. The problem of coupling a spin system to the current in the inductance is studied and the transition is made to the analogous problem of a spin system interacting with a damped mode of a cavity resonator. The analysis is compared with one given previously (Stevens and Josephson, 1959) and it is shown that the results previously obtained in a heuristic way are valid provided that noise fluctuations are negligible.

Diffraction by finite irregular objects. By R. P. Mercier.

In this paper a theory is given of statistical correlation in the complex amplitude of a scalar wave diffracted by an irregular object of limited extent. The theory is one-dimensional, and uses the Fresnel integral to calculate the amplitude at the receiver. Two well-known results appear as special cases. In the first the correlation function of the complex amplitude in the wave is shown to be the same as the correlation function of the complex amplitude at the object if the object is an infinite plane ; this is the basis of irregularity measurement in the ionosphere. In the second the correlation function of the complex amplitude is shown to depend upon the angular distribution of mean power over the source. This is the basis of the Michelson method for measuring the angular diameter of a star. The criterion which distinguishes between the two cases is expressed in terms of the overall size of the object, the irregularity size, the wavelength and the distance from the object.

The similar case of diffraction by a cylindrical object is considered. Here, the criterion distinguishing the two cases involves only the irregularity size and the wavelength. An application to lunar radio echoes is discussed, and it is concluded that the irregularities in the lunar surface cause phase fluctuations much greater than one radian, and these phase fluctuations are correlated over a distance of some 15 meters.

Multiple Geiger counter coincidences due to gamma radiation. By J. C. Barton and E. G. Michaelis.

Triple coincidences produced in Geiger counters by single gamma rays have been found to contribute to the rate of genuine coincidences in unscreened cosmic ray telescopes at great depths below ground.

The effect has been examined by a separate anti-coincidence experiment and has been shown to be compatible with the hypothesis of successive Compton scatters of a single gamma ray quantum in the three counters.

Spin-lattice relaxation in cerium magnesium nitrate at liquid helium temperatures : a new two phonon process. By C. B. P. Finn, R. Orbach, and W. P. Wolf.

The spin-lattice relaxation time of Ce^{3+} in cerium magnesium nitrate has been measured as a function of temperature and magnetic fields up to 1000 gauss. In the temperature range between 3° and 1·9°K, the relaxation time was found to vary exponentially with inverse temperature, changing by a factor of 350. Using a theory appropriate to rare earth salts, the results can be interpreted in terms of a two-step "direct" process. Such a process leads to results which agree both with the experimentally observed temperature dependence and magnitude of the relaxation time.

Polarization of protons from low resonances in $^{12}C(d,p)^{13}C$. By A. G. Gregory and P. B. Treacy.

The polarization of protons from the $^{12}C(d,p)^{13}C$ reaction has been measured at deuteron energies from 790 to 1100kV at angles of 45°, 60°, 90°, 120° and 135°, using a carbon polarimeter. Published angular distributions have been analyzed in conjunction with the present results in terms of compound nucleus theory. Previous assignments of 1^+ and 2^- for the first two levels are confirmed. Analysis of the present results seems to imply a ratio of reduced width amplitudes for d to s wave deuterons larger than that suggested by previous measurements of the angular distribution. However, in fitting these results it was found necessary to assume phase angles other than those required in the usual theory of resonance reactions.

Z-centres in sodium chloride containing calcium. By J. E. Caffyn and B. K. Ridley.

The optical absorption of single crystals of sodium chloride containing calcium as impurity has been measured. Results are given which show a new band at 345 mμ and from measurements of the band width of the F-band it is deduced that the Z_1-band is present in specimens, X-ray coloured, at room temperature.

The growth of the Z-bands on bleaching in samples containing differing amounts of calcium impurity and the effect of quenching was also studied. The concentration of Z-centres was calculated and a theoretical discussion of the mode of incorporation of the calcium in the sodium chloride lattice is given.

Stresses at a crack in an elastomer. By E. H. Andrews.

A microscopical, photoelastic technique has been used to investigate the distributions of stress and strain around a crack in a highly elastic material, natural rubber. The finite strains encountered in such a material give rise to a distortion of the principal-stress map, an effect which has no parallel in classical elasticity and which leads to a complex dependence of the stresses upon the external constraint. The strain energy at a point is however simply related to the external constraint when the latter is expressed in terms of a stored energy parameter T, which is defined. The same parameter is shown to govern the distortion of the stress field. The decay of strain energy in a direction perpendicular to the crack axis is much more gradual when the strains are finite, but the rate of decay along the axis in the elastomer is similar, both in form and magnitude, to that predicted by infinitesimal-strain theory.

A lattice model of a classical hard sphere gas II. By D. M. Burley.

It was shown in a previous publication that the antiferromagnetic Ising model could be transformed to a model of a hard sphere lattice gas. It was seen that, for the loose packed lattice, a phase transition was suggested. It is now shown that on both the Bethe and " ring " approximations that a second order phase transition occurs.

The application of ray tracing methods to radio signals from satellites. By I. N. Capon.

A method of calculating the effect that an ionosphere of given form will have on a radio signal emitted by an earth satellite is described. The method is based on ray tracing techniques, and gives results of very high accuracy. Some results obtained with simple ionospheric models are presented and discussed.

Spin correlation measurements in p-p scattering at 382 and 320 MeV. By J. V. Allaby, A. Ashmore, A. N. Diddens, J. Eades, G. B. Haxtable and K. Skarsvåg.

An account is given of the measurement of the spin correlation coefficients C_{nn} and C_{KP} in p-p scattering at 90° centre of mass scattering angle. C_{nn} was measured at 382 and 320 MeV, C_{KP} at 382 MeV. The method of calibrating the polarization analysers is described and details given of the corrections for random coincidences and for the geometrical contribution to asymmetry. The experimental results were :—

C_{nn} 382 MeV $+0{\cdot}41 \pm 0{\cdot}09$
C_{nn} 320 MeV $+0{\cdot}77 \pm 0{\cdot}11$
C_{KP} 382 MeV $+0{\cdot}63 \pm 0{\cdot}10$

The results are discussed in relation to phase shift analyses and potential models.

S-wave pion-pion interactions. By G. R. Allcock and A. N. Kamal.

The pion-pion interaction has been studied with an explicit appeal to the standard quantum field theory. It is shown that the meson-meson interaction, in the pseudoscalar charge-independent theory, is non-renormalizable in the framework of a positive quantization metric. The short range pion-pion interaction is found to be highly repulsive in states of isobaric spin $I=0$ and 2, giving a hard core scattering. The short range repulsion vanishes in the states with $I=1$. The long range interaction is attractive in the even isobaric spin states but is very small. An " effective " pion-pion coupling constant is obtained in terms of a_0, and a_2, the hard core radii in states of isobaric spin $I=0$ and 2, and μ, the meson rest mass.

$$\lambda_{eff} \simeq \frac{16\,\pi}{5}\,a_0\,\mu \quad \simeq \frac{16\,\pi}{2}\,a_2\,\mu$$

Explanation of some " Forbidden " transitions in paramagnetic resonance. By B. Bleaney and R. S. Rubins.

The abnormal intensity of some " forbidden " hyperfine transitions in the paramagnetic resonance spectra of ions with $S=1$ or more is shown to be due to cross terms in the spin Hamiltonian. These arise from off-diagonal terms in the electronic and nuclear interactions, and the computed transition intensities agree closely with measurements on vanadium fluosilicate. In a powder an apparent doubling of the hyperfine transitions is shown to be due to the combined effect of these terms and others due solely to the electronic splitting.

The Mössbauer effect in tin from 120°K to the melting point. By A. J. F. Boyle, D. St.P. Bunbury, C. Edwards and H. E. Hall.

Measurements have been made of the intensity of the recoilless resonance absorption of the 24 kev γ-ray from the decay of Sn^{119m} in metallic tin from 120°K to the melting point. Values of the Debye-Waller factor deduced from these results tend towards the values calculated for a Debye Θ of 142°K at low temperatures ; the behaviour of the Debye-Waller factor at higher temperatures indicates considerable anharmonicity of the lattice vibrations. Comparison with evidence from the thermal expansion and specific heat suggests that the quartic term in the interatomic potential is positive, and that the ratio of quartic to cubic terms is of the same order as the ratio of cubic to quadratic terms.

In the last few degrees below the melting point the resonance absorption shows a rapid drop accompanied by an increase in line width. It is suggested that this effect is due to enhanced self-diffusion in the solid, and it is estimated that the diffusion coefficient reaches a value of 10^{-8} cm² sec⁻¹ about 0·6°K below the melting point.

Diffraction by an irregular screen of limited size. By B. H. Briggs.

The problem considered is the nature of the diffraction pattern produced by an irregular diffracting screen of limited extent. In particular, the deductions which may be made from measurements of the correlation of the wave disturbances at separated points in the diffraction pattern are discussed. It is shown that such measurements can give information about either the small scale structure of the screen or about its overall extent, depending on the distance from the screen at which the measurements are made. If nothing is known about the nature of the screen or its distance, it is impossible to decide upon the correct interpretation of the measurements unless they are made on more than one wavelength. However, in most experiments enough is known to enable the correct interpretation to be made. Several examples are discussed including measurements of the angular diameters of stars, measurements of the small scale structure of an irregular ionospheric layer, and the problem of reflection from irregular ionized trails produced by meteors.

Scale times and scale lengths of variables: with geomagnetic and ionospheric illustrations. By Sydney Chapman.

The conception of the atmospheric scale height (relating to the proportionate variation of barometric pressure) is generalized to apply to any scalar and vector functions of time and/or position. Examples are given relative to magnetic fields and the ionosphere. The scale length and scale time here defined enable precision to be given to often used terms such as " slow variation ", distance (or time) " small in relation to the scale of variation " of another quantity.

Exchange interactions in the polymorphic forms of MnS. By A. Danielian and K. W. H. Stevens.

Analytically continued high temperature power series expansions developed in the preceding paper are applied to the susceptibilities of the polymorphic forms of MnS, all three of which are known to be antiferromagnetic. An isotropic Heisenberg interaction is assumed between nearest neighbours only.

Estimates of the exchange interaction are obtained using experimental data from the region above the Néel temperature but below the Curie-Weiss region. It is found that $\frac{J}{k}$ is $(12{\cdot}45 \pm 0{\cdot}05)$°K for β-MnS (zinc blende) and $(10{\cdot}75 \pm 0{\cdot}05)$°K for β-MnS (wurtzite). In the case of α-MnS difficulty occurs, using $g=2$, because general arguments show that it is not possible to fit the experimental susceptibility. A fit can be obtained with $g=1{\cdot}8$, but as this is an arbitrary assumption it seems that a full understanding of the properties of α-MnS must await further experiments.

The estimation of antiferromagnetic exchange interactions. By A. Danielian and K. W. H. Stevens.

The estimation of the interaction energies between the magnetic ions in antiferromagnetic crystals is investigated and it is shown that they may be obtained from measurements of the magnetic susceptibility in the paramagnetic phase.

High temperature power series expansions of the zero-field susceptibility—well known in connection with ferromagnetic systems—are analytically continued by means of the transformation $\frac{1}{w}=\frac{1}{z}-\theta$ so that the series no longer diverge at the ferromagnetic Curie point and the domain of convergence is extended towards lower temperatures.

A "level-crossing" experiment in mercury. By John N. Dodd.

A change of the intensity of resonance fluorescence may take place when Zeeman states of the excited level have the same energy. The fields at which these "level-crossings" occur in Hg^{199} and Hg^{201} have been measured. Combined with recent determinations of the hyperfine coupling constants, the results yield values for g_J of the $^3P_1$ states:

$$g_J\,(199) = 1{\cdot}48634 \pm 0{\cdot}00005, \quad g_J\,(201) = 1{\cdot}48606 \pm 0{\cdot}00015.$$

Lattice absorption bands in indium antimonide. By S. J. Fray, F. A. Johnson and R. H. Jones.

A series of detailed measurements of the absorption spectrum of high quality single crystals of *n*-type indium antimonide has been made in the wavelength range 15 to 130μ, and over the temperature range 4·2°K to 90°K.

Some new absorption bands have been found, and an explanation is offered for the position and temperature dependences of all the principle absorption peaks in terms of multiple phonon interactions involving phonons with energies corresponding to temperatures of 259, 224, 169 and 62°K.

Gamma-rays corresponding to a dipole or a high quadrupole excitation of Carbon 12 by 150 MeV protons. By Nicole Gilbert.

The process $^{12}\mathrm{C}\,(p, p'\gamma)^{12}\mathrm{C}$ is formulated in direct interaction theory using the sum rule for the group of dipole states at about 20 MeV and for a group of quadrupole states that we assume to be at about 30 MeV. The angular correlation (p',γ) is discussed and it is shown that for some (p',γ) and (p, p') angles the emission of a E.2 γ-ray in this range of energy has an appreciable possibility.

Infrared investigation of the acceptor levels formed by copper in germanium. By D. L. Greenaway.

Infrared absorption measurements from 1 to 34 microns have been made on germanium containing varying amounts of antimony and copper at temperatures down to 20°K. The results indicate that the three acceptor levels introduced by copper into germanium can be identified by their effect on the low temperature absorption spectra of suitably doped samples. The appearance of the levels is in good agreement with the existing theory, and in addition to this, an excited state of the shallow acceptor level has been identified which has not been previously reported.

The quasi-particle approximation in superconductivity. By P. G. Harper.

A derivation of the BCS and Bogoliubov secular equations by a common method shows that it is necessary to neglect a large number αV^n of small matrix elements αV^{-n} where V is the volume of the system and n an arbitrary positive integer. A generalization of the Bogoliubov fermion transformation which diagonalizes these terms takes the form of an infinite series whose convergence may depend on the form of the interaction.

Paramagnetic resonance absorption in bromine and chlorine. By J. S. M. Harvey, R. A. Kamper and K. R. Lea.

The microwave Zeeman spectra of atomic chlorine and bromine have been observed. From measurements on several lines in the spectrum of the $^2P_{3/2}$ ground level, the electronic *g*-factors are found to be

$$g_J(\mathrm{Br}) = 1{\cdot}333921 \pm (4 \times 10^{-6})$$
$$g_J(\mathrm{Cl}) = 1{\cdot}333927_5 \pm (2 \times 10^{-6})$$

An estimate of relativistic and diamagnetic corrections to the *g*-factors, based on self consistent field wave functions, is in satisfactory agreement with the experimental results. A comparison is made with the *g*-factors of fluorine and iodine.

The photoproduction reaction $^{60}\mathbf{Ni}(\gamma, \pi^-)^{60}\mathbf{Cu}$. By P. V. March and T. G. Walker.

The cross-section for the reaction $^{60}\mathrm{Ni}(\gamma,\pi^-)^{60}\mathrm{Cu}$ has been measured using bremsstrahlung having maximum energies from 120 MeV to 320 MeV. Radiochemical separation techniques were used to separate the ^{60}Cu from the other activities produced by the irradiation. A comparison with previous results for the reaction $^{11}\mathrm{B}(\gamma, \pi^-)^{11}\mathrm{C}$ indicates that the reaction is due predominantly to surface production.

Some notes on theories of helium. By F. J. Pearson.

Attention is directed to that approximation to the quantum mechanical partition function for an imperfect fluid which is afforded by assuming the commutation of the kinetic and potential energy operators. The corresponding grand partition function is developed in the form of a cluster integral series, and discussion of its behaviour at low temperature is facilitated by a further approximation. This leads to equations for the pressure and density which are similar to the classical expressions of Mayer, and which afford a qualitative description of the condensation of helium into liquids I and II. Numerical calculation shows not unreasonable agreement with experiment. Finally the theories of Chester and Feynman are discussed in more detail in relation to these cluster integral expansions.

Isotope effect in band spectra of magnesium oxide. By D. S. Pesic.

Some studies of the electronic spectrum given by magnesium in a vacuum arc in oxygen 18, and in a mixture of O^{16} and O^{18} have been made. The measurements of isotope shift are given for the green and for the ultra violet system. The isotope effect in the green system confirms the vibrational analysis of Mahanti and Lagerqvist. The bands in the ultra violet region are again attributed to a polyatomic molecule containing magnesium and oxygen atom. The assignment is partly supported by the isotope shift, but the molecule only contains a single oxygen atom.

The evaluation of partial wave integrals in the Born approximation. By M. J. Seaton.

The Born partial wave integrals may be evaluated on making a harmonic analysis of the integrals occurring in the Born total scattering amplitude. This provides a convenient method for numerical evaluation of the partial wave integrals. The paper includes the proofs of an addition theorem for solid harmonics and a multiplication theorem for spherical Bessel functions.

The calculation of Born partial wave integrals for some transitions in H produced by electron impact. By J. Lawson, W. Lawson and M. J. Seaton.

Using methods described in the preceding paper, the partial wave integrals are calculated for transitions involving the states $1s$, $2s$, and $2p$.

The calculation of electron-hydrogen collision cross-sections using the Born approximation for the reactance matrix. By V. M. Burke and M. J. Seaton.

Lawson, Lawson and Seaton (1960) have calculated the Born R Matrix for H $1s$, $2s$ and $2p$. Using these results the transmission matrix is calculated from $T = -2iR/(1-iR)$. Seaton (1960) has shown that this should give results which are better than those obtained from the Born approximation for the total scattering amplitude.
The following cross sections are calculated : elastic ($1s-1s$, $2s-2s$, $2p-2p$) ; momentum loss ($1s-1s$, $2s-2s$, $2p-2p$, $2s-2p$) ; inelastic ($1s-2s$, $1s-2pm_l$) ; transitions between fine structure levels ($2s_{\frac{1}{2}}-2p_{\frac{1}{2}}$, $2s_{\frac{1}{2}}-2p_{3/2}$, $2p_{\frac{1}{2}}-2p_{3/2}$). Comparison with experiment shows our results for $1s-2p$ to be much better than those obtained from the usual Born total amplitude.

Strong coupling in optically allowed atomic transitions produced by electron impact. By M. J. Seaton.

Optically allowed transitions have long-range interaction potentials, behaving asymptotically as s_1/r^2 where s_1 is proportional to the dipole matrix element. In calculating cross sections many angular momentum states l must therefore be considered. When the coupling is strong the usual Born approximation leads to violations of conservation conditions which are serious for the smaller values of l. Three variants of the first Born approximation are considered : I is the Born approximation for the total scattering amplitude, II the Born approximation for the reactance matrix and III (suggested by Percival) the Born approximation for the proper phase of the scattering matrix. Approximations II and III satisfy conservation conditions and make some allowance for processes such as $\alpha \rightarrow \alpha' \rightarrow \alpha$, $\alpha \rightarrow \alpha' \rightarrow \alpha''$ and of $\alpha \rightarrow \alpha''$ competing with $\alpha \rightarrow \alpha'$.
Considering the case of exact resonance, and replacing the potentials by their asymptotic forms, one obtains equations for which exact analytic solutions may be obtained. The exact solutions are compared with those obtained using approximations I, II and III.

Fine structure in the $C^{12}(\gamma,n)C^{11}$ activation curve. By I. M. Thorson and L. Katz.

Fine structure in the $C^{12}(\gamma,n)C^{11}$ activation curve has been examined in great detail. Eighteen breaks were found between threshold and 23 MeV. The positions of these breaks and the integrated cross sections of the corresponding levels for the (γ,n) reaction are listed. Independent measurements in other laboratories have indicated that resonance photon absorption into discrete levels may also be present for the (γ,p) reaction. The failure to observe structure in the (p,γ) inverse reaction thus remains unexplained.

A study of the reactions $^{12}C(^3He,n)^{14}O$ and $^{16}O(^3He,n)^{18}Ne$. By J. H. Towle and B. E. F. Macefield.

The time of flight and slow-neutron threshold techniques in conjunction with ^3He particles of energies of up to 11 MeV, have been used to measure the Q value of the $^{16}O(^3He,n)$ reaction and to locate levels in ^{14}O and ^{18}Ne. The Q value, $-3{\cdot}199 \pm 0{\cdot}006$ MeV, requires a mass defect of $10{\cdot}649 \pm 0{\cdot}008$ MeV for ^{18}Ne. Levels were found in ^{14}O at $5{\cdot}905 \pm 0{\cdot}012$, $6{\cdot}30 \pm 0{\cdot}03$, and $6{\cdot}586 \pm 0{\cdot}012$ MeV ; and in ^{18}Ne at $1{\cdot}880 \pm 0{\cdot}010$, $3{\cdot}362 \pm 0{\cdot}011$ and $3{\cdot}608 \pm 0{\cdot}012$ MeV.
Excitation functions were measured between 2·0 and 5·7 MeV for both reactions. Angular distributions of the $^{12}C(^3He,n)$ reaction measured at 4·65, 4·98 and 5·26 MeV, have been compared with theory for a double stripping process. The data suggest that a direct process is competing strongly with compound nucleus formation in this energy region.

The effect of attenuation on the acoustic resonant frequencies of gases in tubes. By H. J. Wintle.

The change in the resonant frequencies of a sound tube due to the dependence of attenuation on frequency is worked out for two cases of practical interest. The effect on measured values of the velocity of sound is shown to be significant in accurate work.

RESEARCH NOTES AND LETTERS TO EDITOR

The elastic scattering of ^3He by ^3He. By B. H. Bransden and R. A. H. Hamilton. (Research Note).

Antiferromagnetic behaviour of GdB_6. By B. R. Coles and D. Griffiths. (Letter to Editor).

Soft X-ray emission spectra of some transition and noble metals. By C. Curry and D. J. McNeill. (Research Note).

Catalytic magnetization of atomic hydrogen. By S. Doniach. (Research Note).

Speculation on the centres formed by nitrogen in diamond. By R. J. Elliot. (Research Note).

A note on electroluminescence due to carrier accumulation. By H. K. Henisch and B. R. Marathe. (Research Note).

The Knight shift in alloys. By W. G. Henry. (Research Note).

The infra-red absorption spectra of potassium manganicyanide and vanadium corundum. By G. D. Jones and W. A. Runciman. (Research Note).

Hall constant and electrical conductivity measurements on lead selenide single crystals grown from the vapour. By R. H. Jones. (Research Note).

A further explanation of the shape of the hysteresis loop of " square loop " ferrites. By J. E. Knowles. (Research Note).

Features of the elastic wave surface for a zinc crystal. By M. J. P. Musgrave and M. F. Markham. (Research Note).

The measurement of indirect (J) coupling between nuclei in liquids in magnetic resonance by the transient method. By J. G. Powles and A. Hartland. (Research Note).

Nuclear resonance absorption of ultra sound in KI and KBr. By G. S. Verma and S. K. Joshi. (Letter).

RESEARCH and DEVELOPMENT DEPARTMENT

BERKELEY NUCLEAR LABORATORIES

Physics Division

The Laboratories under construction at Berkeley, Gloucestershire, on a site adjacent to the Berkeley Nuclear Power Station, are now nearing completion. They will carry out the major part in the Board's experimental nuclear research and development programme. **Applications are invited for a number of vacant posts in the Physics Division.** Persons appointed will initially work in the following sections, although subsequent transfer between sections will be permissible, depending on the developing interests and abilities of the staff concerned.
Previous experience in a related field is an advantage, but is not essential, as training will be provided where necessary.

A. SOLID STATE PHYSICS

For work on the fundamental physics of graphite, and measuring changes in the properties of the graphite in the Board's reactors, during the whole reactor life. Previous experience in X-ray crystallography will be an additional advantage for one of these vacancies.

B. THEORETICAL PHYSICS

For work on various theoretical problems of interest to the Laboratory, including reactor physics and the theory of radiation damage.

C. REACTOR PHYSICS

For work on experimental sub-critical reactor problems and experiments connected with the Board's reactor programme. In view of the growing demand for reactor physicists, these posts, for which training is offered, are of considerable interest to young men with energy and ability, who wish to enter this field.

D. INSTRUMENTATION

For work developing nuclear radiation detectors and other specialized nuclear instruments. Preference will be given to candidates who are capable of devising and developing new techniques of measurement.

The range of salaries for Research Officers extends from £650 - £2,395 p.a. according to duties and responsibilities. The present posts are advertised in the range £1,335 - £2,085 p.a. and there are some posts available in the lower range.
Applications, stating age, qualifications, experience, present position and salary, to the Personnel Officer, 24/30 Holborn, London, E.C.1, as soon as possible. Envelopes should be marked "Confidential Ref. PB/305".

CENTRAL ELECTRICITY GENERATING BOARD

ICI

ENGINEERS PHYSICISTS

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These vacancies are additional to the normal requirements for engineers in the Company.
Previous experience in the textile machinery industry is not essential — experience in the aircraft, motor car, guided missile or atomic energy industries might well enable applicants to bring new techniques to this field.
Conditions include five-day week, canteen facilities, Staff Pension Fund and Employees Profit Sharing. Assistance to married men to enable them to move into the district is available in the form of mortgage facilities, removal expenses and lodging allowances.

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FIBRES DIVISION, HARROGATE, YORKSHIRE
Quoting Reference T.14/B

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BILLINGHAM DIVISION

Honours Graduates in Physics for Instrument Work

The Billingham Division of Imperial Chemical Industries Limited requires **PHYSICISTS** for work in the Instrument Development Section on analysis and other instruments, on automatic control problems and data reduction systems. Experience may also be given in the Factory Instrument Service. A good Honours Degree in Physics is required and experience in some field of instrumentation is desirable but not essential.

Salaries are attractive, there is a Profit-Sharing Scheme, lodging allowances are payable and some help may be given with housing.

ICI

Applicants should write to:

The Staff Manager,
Imperial Chemical Industries Limited,
Billingham Division,
Billingham,
Co. Durham

giving brief particulars of qualifications and experience and quoting reference R/A.2.

EAST AFRICA HIGH COMMISSION

METEOROLOGISTS

EAST AFRICAN METEOROLOGICAL DEPARTMENT

Qualifications: Candidates (men or women) must possess a good honours degree in mathematics and/or physics. Experience in a Meteorological Service, especially in analysis and forecasting, useful but not essential. Successful applicants with no previous experience will normally be given training.

Duties may include weather analysis and forecasting (including research); consultative meteorological work related to agriculture, hydrology, etc.; research into climatology, rain stimulation, evaporation control; work in the field of geomagnetism or solar radiation.

Terms of Appointment; *On probation to the permanent and pensionable establishment; or on contract for one tour (30-36 months) in the first instance with gratuity on satisfactory completion of service. Salary according to experience in the scale £939-£1,863 p.a.* (*permanent terms*) *or £1,107-£1,863 p.a.* (*contract terms*). *Outfit allowance. Free passages. Quarters provided at rental if available. House or hotel allowance if quarters not provided. Generous leave. Medical attention available. Taxation at local rates.*

Apply to Director of Recruitment, Colonial Office, London, S.W.1. State full name, age, qualifications and experience. Quote BCD 57/88/01/BIP.

NATIONAL PHYSICAL LABORATORY, Teddington, Middlesex, requires SCIENTIFIC/SENIOR SCIENTIFIC OFFICERS as follows: Basic Physics Division—Physicist for work on static or dynamic properties of high polymeric materials. Experience of polymer physics desirable. Qualifications: 1st or 2nd Class Hons. degree or equivalent (Ref.: A.321/OA). Mathematics Division—Mathematician or Physicist for (*a*) numerical analysis, both application of existing methods and development of new techniques; particularly application thereto of high speed computers; (*b*) development of high speed digital computer techniques in various fields. Qualifications: 1st or 2nd Class Hons. degree, or equivalent, in Maths. or physics. (Ref.: A.318/OA). For Senior Scientific Officer at least three years' postgraduate experience required. Min. age 26. Salary ranges (Men) Scientific Officer £730–£1,205, Senior Scientific Officer £1,330–£1,640. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting appropriate Ref. No. Closing date September 24, 1960.

Due to expansion of their experimental facilities G. V. PLANER LTD., consultants and research laboratories, have the following new vacancies: SENIOR PHYSICIST OR CHEMIST for work on semiconductors and devices. PHYSICISTS OR CHEMISTS (2) for research on semiconductors and dielectrics. PHYSICISTS OR CHEMISTS (2) for research in electrical thin films. LITERATURE/PATENT ABSTRACTOR for searches in electrical materials. The posts carry attractive salaries; pleasant working conditions. The laboratories are close to a good residential area. Informal interviews arranged at Sunbury or London any time including evenings or week-ends. G. V. Planer Ltd., Windmill Road, Sunbury-on-Thames, Middlesex (Sunbury 2266).

UNIVERSITY OF CANTERBURY
CHRISTCHURCH, NEW ZEALAND

SENIOR LECTURER IN MATHEMATICS

Applications are invited for the abovementioned post. Qualifications in either pure or applied mathematics will be acceptable and the appointee will be expected to engage in research in his own field or to assist with work in the field of rocket trajectories and space navigation already in progress in the mathematics Department. The salary will be at the rate of £1,750 per annum, rising by two annual increments of £100 and one of £50 to £2,000 per annum. Commencing salary in accordance with qualifications and experience. Approved fares to Christchurch will be allowed for the appointee, his wife and children, together with actual removal expenses within certain limits. Further particulars may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in New Zealand and London, on September 16, 1960.

UNIVERSITY OF NEW ENGLAND
ARMIDALE, N.S.W., AUSTRALIA

SENIOR RESEARCH FELLOW IN PHYSICS

Applications are invited for the abovementioned position. The appointment will be made for two years on a salary of £A3,000 per annum. The Senior Research Fellow will be required to take part in a research programme to study the action of very powerful beams of gyro-waves on the Ionosphere. Provision is made for the payment of travel and removal expenses to and from Australia. Further information may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in Australia and London on September 30, 1960.

AIR MINISTRY

SCIENTIFIC ADVISER DEPARTMENT

AIR MINISTRY requires graduates in Mathematics, Physics or Engineering. Graduates in other scientific disciplines who apply should possess some mathematical knowledge and ability. Qualifications First or Second Class Honours Degree.

Scientific Staff are concerned with studies and giving advice on problems of effectiveness, cost and reliability of weapon systems, on planning, strategy and tactics of Royal Air Force operations and on interpretation of weapon trials. Also concerned with development of operational research methods and techniques and with application of electronic computers and simulators. Work involves close co-operation with officers of Royal Air Force at all levels. Vacancies are mainly at Headquarters in Whitehall, London, but also in Royal Air Force Command Headquarters and Development Units in United Kingdom. Salaries: London men Senior Scientific Officers £1,330–£1,640; Scientific Officers £730–£1,205. Outside London slightly lower. Women will receive equal pay in 1961. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quoting A.104/OA). Closing date September 26, 1960.

PHYSICISTS

(MEN AND WOMEN)

required for RESEARCH AND DEVELOPMENT ESTABLISHMENTS of War Office (mainly in Southern England) offering wide range of work including classical physics, electronics, technical optics, ground and hydrographic survey equipment, detonation physics, biophysics, instrumentation, operational research. Locations include: Sevenoaks, Kent; Byfleet, Tolworth and Chertsey, Surrey; Shoeburyness, Essex; Salisbury, Wilts; Farnborough, Hants. Appointments in grades of (*a*) SENIOR SCIENTIFIC OFFICER £1,250–£1,540 or (*b*) SCIENTIFIC OFFICER £690–£1,145. Starting salary according to experience (women's rates the same by 1961). Superannuations under F.S.S.U., with opportunity for candidates under 31 to compete for established pensionable posts. 1st or 2nd Class Hons. degree or equivalent required and for (*a*) min. age 27 and at least three years' postgraduate research experience. Forms from Technical and Scientific Register (K), Ministry of Labour, 26 King Street, London, S.W.1, quoting A.301/OA.

VICTORIA UNIVERSITY OF WELLINGTON

NEW ZEALAND

SENIOR LECTURER IN PHYSICS

Applications are invited for the abovementioned post. The salary will be £1,750 per annum, rising by two annual increments of £100 and one increment of £50 to £2,000 per annum. The initial salary will be determined according to the qualifications and experience of the appointee. Approved fares to Wellington will be allowed for the appointee, his wife and his dependent children. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in New Zealand and London, on October 31, 1960.

MATHEMATICIANS, SCIENTISTS AND ENGINEERS required by ARMY OPERATIONAL RESEARCH ORGANIZATION (War Office), West Byfleet, Surrey, for assessment of performance and potentialities of weapons and equipment, study of problems connected with tactics and conduct of military operations, supply and maintenance of military stores, human performance and selection and training of manpower. Scope for use of practically all scientific training provided this is backed by a certain minimum mathematical ability. Work is varied and interesting and there are laboratory and workshop facilities. Appointments in grade of (*a*) SCIENTIFIC OFFICER (£690 to £1,145) or (*b*) SENIOR SCIENTIFIC OFFICER (minimum age 26 and at least three years' postgraduate research experience) (£1,250-£1,540). First or second class honours degree or equivalent required for both. Superannuation under F.S.S.U. Those under 31 have opportunities for establishment. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.198/OA.

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

DEPARTMENT OF MATHEMATICS

STAFF VACANCIES

(Permanent and Temporary)

Applications are invited for appointment either on a permanent basis, or on a temporary basis for a period of two to three years, to posts of Senior Lecturer and Lecturer in Mathematics. Duties are to be assumed on the earliest possible date in 1961. The salary of a Senior Lecturer is according to the scale £1,590 × £60 – £2,070 per annum and that of Lecturer, £1,230 × £60 – £1,710. The initial notch will be determined in accordance with the qualifications and experience of the successful candidate. Special arrangements are made for travelling expenses for both temporary and permanent appointments. Intending applicants may obtain a copy of the information sheet relating to these vacancies from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. The closing date for the receipt of applications in Johannesburg and London is October 15, 1960.

COURSES

SURREY COUNTY COUNCIL

EWELL COUNTY TECHNICAL COLLEGE

A course of 12 weekly lectures entitled "Transistors and their Applications" will commence on Wednesday, September 28, 1960. The course is suitable for the circuit engineer and physicist, and will be given by the staff of the Mullard Research Laboratories. For details apply to the Head of the Science Department, Ewell Technical College, Reigate Road, Ewell, Epsom, Surrey. Telephone Ewell 5025. Fee for course will be £1 2s. 6d.

ROYAL TECHNICAL COLLEGE, SALFORD

DEPARTMENT OF PURE AND APPLIED PHYSICS

RADIOLOGICAL HEALTH AND SAFETY

A postgraduate course in Radiological Health and Safety, of one academic year's duration, will be held during the forthcoming session, 1960-61. This is intended for graduates or those of graduate status and will deal with the principles and practice of radiation protection. Laboratory work will be an integral part of the course. Suitable Candidates can be considered for the award of a D.S.I.R. grant for this course. Satisfactory completion will qualify for a College Certificate. The fee for the course is £81. Further details may be obtained from the Acting Head of Department.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

DEPARTMENT OF APPLIED PHYSICS

COURSE ON

RECENT ADVANCES IN SOLID STATE PHYSICS

A Short Course for Physicists and Engineers on Recent Advances in Solid State Physics will be held on Thursday and Friday, October 27 and 28, 1960. Fee: £1 2s. 0d. Full particulars and forms of application from the Head of the Department of Applied Physics.

UNIVERSITY OF LEEDS

HOULDSWORTH SCHOOL OF APPLIED SCIENCE

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OCTOBER 17–DECEMBER 2, 1960

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A PHYSICS ANTHOLOGY

EDITED BY

NORMAN CLARKE

Deputy Secretary, The Institute of Physics
and The Physical Society

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